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TWELFTH CHEMICAL EXPOSITION NUMBER

PROCESS CONTROL

CHEMICAL & METALLURGICAL ENGINEERING

VOLUME THIRTY-SIX – NUMBER FOUR

APRIL, 1929

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VOLUME THIRTY-SIX - NUMBER FOUR

APRIL, 1929

S. D. KIRKPATRICK, *Editor*

PROCESS CONTROL

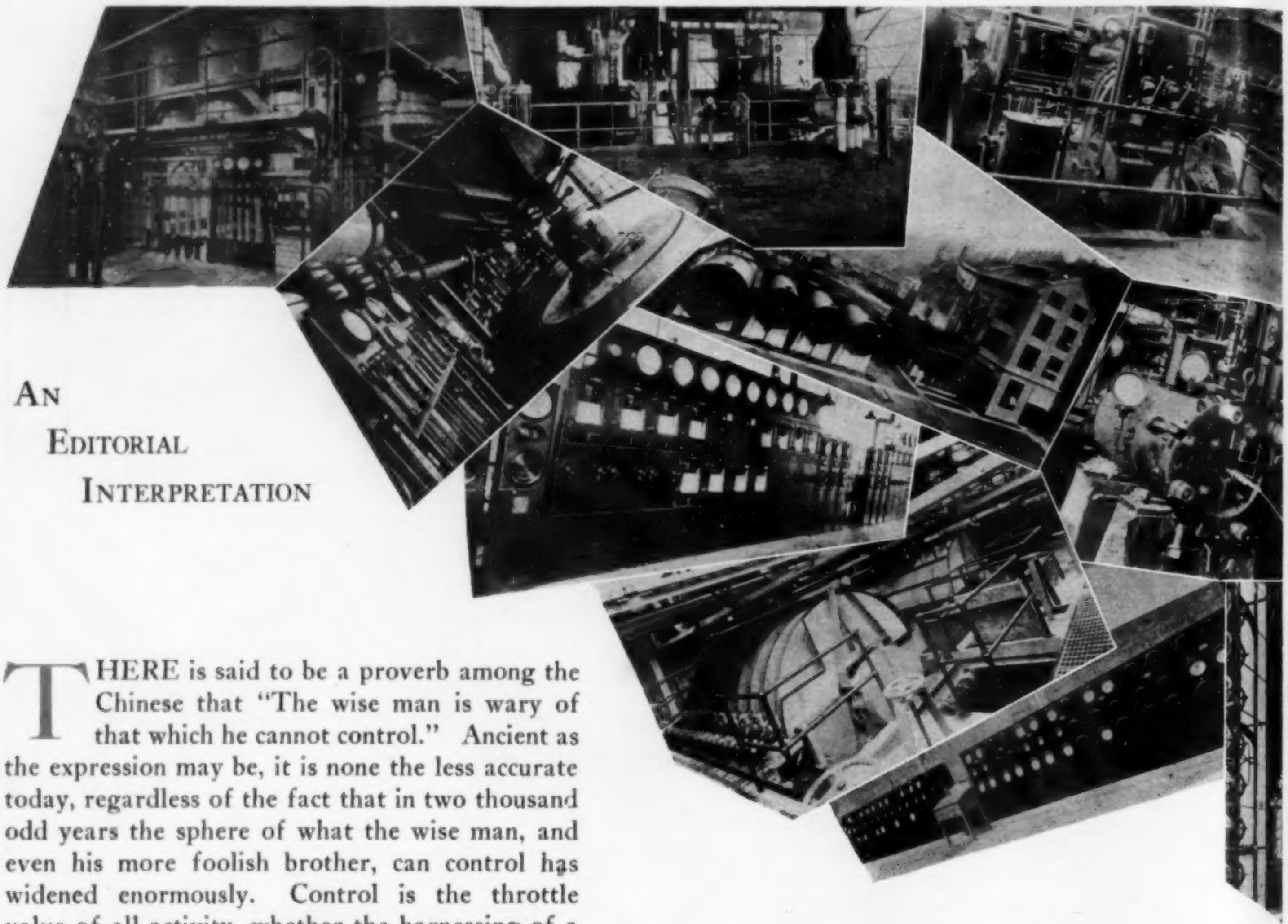
THE CHEMICAL ENGINEER'S CONTRIBUTION TO INDUSTRIAL PROGRESS

IF IT BE TRUE THAT WE ARE LIVING IN A MACHINE AGE, that mechanization is the dominant characteristic of our industrial civilization, it is because we have mastered many forces. Control has become the determining influence in our progress. As it spreads from industry to industry we see empiricism displaced by scientific knowledge. Precision and economy supplant the guesswork of wasteful, rule-of-thumb methods.

CHEMICAL ENGINEERING HAS CONTRIBUTED MUCH to the progress of control. From its modest beginning in the chemical laboratory, the influence of the chemical engineer has extended to the control of manufacturing operations in more than twenty industries. In this spread of technology, the Chemical Exposition as an institution has played a peculiarly important part. Interchange of knowledge and experience through the printed word has been supplemented and confirmed by the Exposition's practical demonstration of new developments in materials, processes and equipment. The Twelfth Exposition of the Chemical Industries, to be held in New York during the week of May 6, offers the chemical engineer and industrialist the opportunity to learn and to profit from the achievements of those whose business it is to develop new materials and more efficient tools for the chemical engineering industries.

WITH THE COMPETENT HELP OF MANY CONTRIBUTORS, CHEM. & MET. is privileged in this issue to present a cross-section of our knowledge of process control. To the chemical engineer it is a challenge for still greater achievement. Instruments, machines and accumulated experience are now available for controlling most, if not all, of the complicated variables of the process itself. There remain the problems of co-ordination, the proper balancing of all of the factors—human as well as mechanical, economic as well as technical—that make for successful plant operation. It is in the discharge of this broader responsibility that the chemical engineer demonstrates his true worth to industry.

The Rôle of CONTROL *in*



AN
EDITORIAL
INTERPRETATION

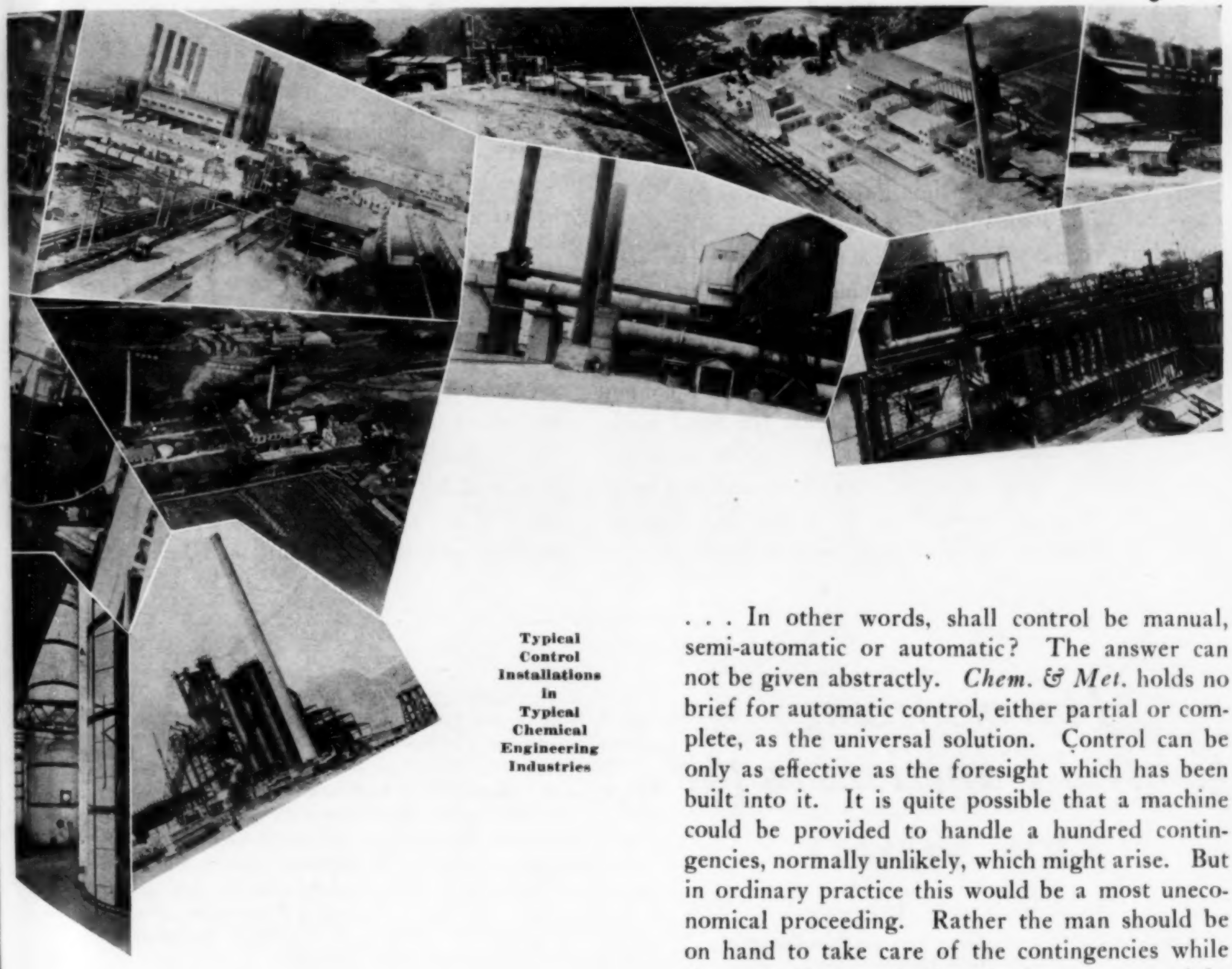
THERE is said to be a proverb among the Chinese that "The wise man is wary of that which he cannot control." Ancient as the expression may be, it is none the less accurate today, regardless of the fact that in two thousand odd years the sphere of what the wise man, and even his more foolish brother, can control has widened enormously. Control is the throttle valve of all activity, whether the harnessing of a Niagara or the setting of a mousetrap, whether it involves the direction of a razor or the guidance of an army.

. . . It is a wise man who knows how to control his own chemical plant, let alone the world's Niagaras. For control means more than the regulation of mechanical agencies which can reasonably be expected to travel in predetermined grooves once they are properly set in motion. It involves also problems of organization, questions of the unforeseen and the captaining of the human animal in all his inherent limitations and innate perversity. This is the reason *Chem. & Met.* has not limited the discussion of PROCESS CONTROL to the regulation of the inanimate, but has included in addition topics from the human angles of the question.

. . . What does control mean to the chemical engineering industries? Webster is of small assistance—to curb, restrain, exert a guiding influence. To be sure, but in addition it means smooth, harmonious operation, safety and efficiency, a uniformly excellent product. It means high wages, satisfied labor and profits. In short, without control, the agencies—human and inanimate—that should be at the command of industry would be worthless for productive effort, or even dangerous things of which the wise man is wary if he justify his wisdom.

. . . Although control of the human variable in the industrial equation is beyond compass of any formula, when it comes to control of the chemical, mechanical and physical *X*'s and *Y*'s, our ideas are more easily formulated—witness the majority of the following pages. Here the reader may expect to find bread-and-butter facts as well as food for thought in the expedients which other engineers have applied successfully in their own industries. In later pages he will find a great deal of

Chemical Engineering Industries



Typical Control Installations in Typical Chemical Engineering Industries

information on apparatus that has been designed to control a wide variety of the mechanical and physical variables that enter into chemical processing; further pages show the application of automatic control technique in the chemical engineering unit processes.

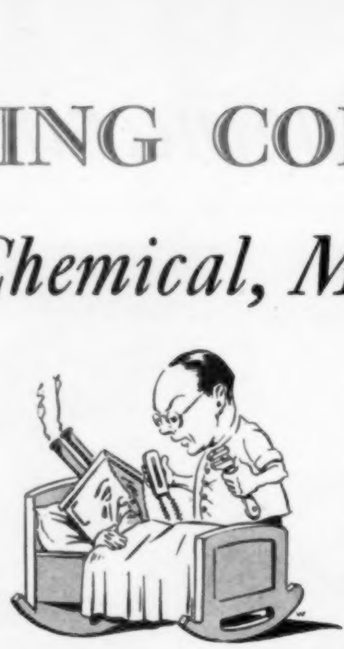
. . . How can we apply these devices to control the inanimate variables? The answer is simpler than its practice: Control equals measurement plus the intelligent application of the best of known principles. Assuming that the principles are known, it is necessary to measure accurately—a thing which man cannot do without standards, and equipment for their interpretation. These are, fortunately, available in great profusion and the question becomes one of finding the most effective way in which to apply the principles.

. . . In other words, shall control be manual, semi-automatic or automatic? The answer can not be given abstractly. *Chem. & Met.* holds no brief for automatic control, either partial or complete, as the universal solution. Control can be only as effective as the foresight which has been built into it. It is quite possible that a machine could be provided to handle a hundred contingencies, normally unlikely, which might arise. But in ordinary practice this would be a most uneconomical proceeding. Rather the man should be on hand to take care of the contingencies while the controller remained to do the one or two jobs in which it bettered the man. And there is no doubt but that the mechanism *can* improve upon the man in certain respects, for its intelligence—so far as it goes—may be made unfailing. Nevertheless it is sufficiently difficult to teach new tricks to an old controller without expecting it to evolve them spontaneously in the event of unforseen happenings.

IN THE last analysis, therefore, whether we emulate the ostrich or no, the economical answer will be the correct one. Control automatically, by all means, within the bounds of the economically arrived-at intelligence of the machine. And since the intelligent machine, no less than the wise man, should be wary of that which it cannot control, the human element must remain, willy-nilly, at the call of the mechanism.

CO-ORDINATING CONTROL

of the Chemical, Mechanical and



ONE OF THE MOST TRYING PERIODS in the life of a chemical plant is that time during its infancy when the management has to nurse it through a round of industrial measles, mumps and chicken pox, the period when the product is poor, the yields worse and the profits buried deep beneath a column of red figures. It is a time for hard work, patience and not a little of inspiration, when the "bugs" must be worked out and new operating personnel must be broken in. Concentrations are in doubt, temperatures are not definitely known, and if the process is a new one, very probably a considerable amount of apparatus will be up for re-design before the growing pains are subdued.

CONTROL MUST BE CO-ORDINATED. That consitutes the major problem. But there is no royal road to co-ordination. The difficulties that beset one plant may largely differ from those encountered in another of the same breed and be absolutely at variance with the troubles that make life hide-

Harmonizing Control Functions in the NEW PLANT

By THOMAS R. HARNEY

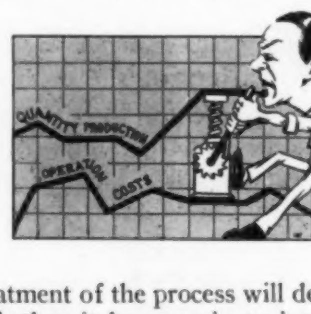
Superintendent, Acid Division, Monsanto Chemical Works Monsanto, Illinois

PROPERLY co-ordinated control in a chemical plant is easy to recognize but not so easy to attain. The writer is perhaps in the position of the famous epicure who, while fully qualified to criticize an omelet, was totally lacking in the requisite culinary skill for its construction. Yet, there are certain elements in the making of omelets that everyone really knows, if only he will pause to recognize them.

The general question of co-ordination of control is a broad one, for it extends from the upper levels of administration down to the individual operator and his helper. Any short statement of what it involves is therefore likely to be both uninteresting and misleading. There are a number of general points, however, which can be developed as applying throughout industry.

Co-ordination of the various activities of any given plant always proves to be a function of a number of complex variables,—and it is not a function that can be evaluated by other than cut-and-try methods. Among these variables we find the matter of process, the size of the plant, the relation of the department in question to the rest of the plant, and the allocation and extent of authority vested in the operating department. These are typical of the parts which must be made to fit accurately into the whole.

The process is of primary interest to the operating department. It may be a duplication of an old and well-known operation or it may be a new form of manufacture which has been through only the semi-plant scale; the new plant may run the entire gamut of variations between these two extremes; plant capacity may be out of line with previous experience although a duplication of something that is known. All these factors tend to complicate the proper co-ordination of process.



Again, treatment of the process will depend to a certain extent on whether it be organic or inorganic. If it be the latter, it will, in general, depend for economic success upon quantity production, low operating cost and low overhead. The spread will probably be insignificant per pound, the profit per ton only a few dollars or possibly only a few cents. The yield is not a matter of unconcern, but within reason, it will be less important than operating expense. On the other hand, however, if the plant be engaged in an organic process, high yield will be of prime importance. Automatically, highly accurate control of the process and perfection of equipment become major problems.

Human Variables IN INDUSTRY

ous for the superintendent of still a different sort of process plant. In general, however, the chief problems in the early stages of co-ordination of control lie in breaking in the new operator or accustoming experienced men to new routine and in the actual physical process of persuading the elements of the plant to work in harmony with each other.

WHILE THE EDITORS REALIZE FULL WELL that there is no touchstone for the harassed superintendent and that it is quite impossible to lay down any hard and fast set of rules for control co-ordination, *Chem. & Met.* has nevertheless thought it worthwhile to pass on some of the boiled-down experience of two men, each of whom has the background to speak with unusual authority. Thomas R. Harney, from the viewpoint of the heavy-chemical man, writes of the problems of co-ordinating control; and Louis Fenn Vogt, with long experience in an important branch of the chemical industry, has been asked to handle the subject of breaking in the new operating man. Each of these engineers has a message that will pay generous dividends for a few minutes of careful study by any reader in chemical engineering industries.

The size of the company and the nature of the upper organization structure must be taken into consideration. Further, the type of personnel involved in the co-ordination is all-important in determining the limits to which authority may be extended. This authority must be definitely allocated so that there shall be no question as to its scope and extent. There is much needless friction arising where responsibility is not accurately placed.

A FEW FUNDAMENTAL principles for the delegation of authority may well be set down at this point, but even these are subject to alteration by one or more of the factors noted above. The problem becomes relatively simple in a plant of small size and limited sphere of activity. In the large plant, however, one of the first matters to be taken in hand is the relation between departments. One simple generality exists, namely a rule for the placing of inter-department responsibility and the location of the points of inter-department contact. Almost without exception, definite individuals must be designated for these contact points. Elementary as this principle is, it is astonishing to observe the number of instances in which it is overlooked.

To become specific—what, for instance, is the connection between operating department and engineering, maintenance, control, sales, purchasing, research and treasurer's departments? In the small plant several of these functions may be vested in one man or in two or three men at most, all of whom are in touch with one another's problems and work closely together. In this case, the superintendent, in charge of operations, will probably have direct control over each of these departments except perhaps sales and accounting. But when the plant is large, separation of functions is imperative. Then the necessity for a definite line of communication between operations and other plant divisions becomes of greatest importance.

The confusion resulting from miscellaneous orders, written or oral, flowing between departments in regard

to department affairs is frequently enormous. Particularly, direct communication between the operating and engineering, purchasing and maintenance departments must be clear cut and well defined. When this has been accomplished, a very substantial part of the difficulty attendant upon the early stages of plant operation has been brought into line. It is perhaps the single most important principle in co-ordination of control.

WITHIN the operating department itself, authority must be designated with equal clarity. To what extent, for example, may an operating man, say a foreman or a supervisor, order maintenance work? The answer will, of course, depend both upon the magnitude of operations and the personnel variable previously referred to. Allocation of similar authority for the carrying out of other contacts will be similarly dependent.

Nevertheless, many companies, due to their size necessarily attempt, more or less successfully, to make the authority constant and to vary personnel.

In the actual working out of technical matters the operating department must be given as free a hand as possible. It is here that the inertia inherent in a highly departmentalized organization may play havoc. The small company will probably have little to complain about but the ponderous, many-departmented concern will frequently have various elements working at cross purposes. As an example, absentee control of the purse strings is a particularly annoying feature. In one large organization, with 12 to 13 million dollars invested in its plants, the highest officer in the plant, in whose hands was placed the responsibility for all aperations, had the power to authorize expenditures, even for necessary maintenance to the extent of only \$100. His chief supervisors, each of whom was responsible for very extensive operations, were able to spend only sums up to \$25. It is needless to expand upon the difficulties which were met in carrying on normal operation, to say nothing of plant improvement.

Departmentalization may also allocate other responsibilities in adverse relationship to the operating division. Laboratory control is a case in point. It cannot reach maximum efficiency when it is made a function of a non-operating-department laboratory. This does not obtain for finished goods inspection nor shipping specifications but it is assuredly true for routine control. In heavy chemicals, it is even questionable how much value there is in chemical control of a nature preventing its exercise by the operator or supervisor. Naturally, in the more complicated processes of organic chemistry, close laboratory supervision is desirable but here again this supervision is very preferably an operating department function.

There is a phase of process control which is inevitably an operating department matter. The question in this case is not one of the allocation of authority but rather the extent to which the control is to be utilized. Automatic process control has not yet gained much foothold in the acid and heavy chemical industry but automatic process *observation* through the use of recording instruments such as thermometers, pyrometers, gas analyzers and titrimeters has properly become quite common. Even this use, however, must be qualified by a limitation. Automatic observation cannot replace the human element completely if trouble is to be avoided. The writer favors the use of automatic observation equipment to reduce the operator's work by perhaps 50 per cent, meanwhile requiring periodic personal control checks, preferably expressed in different units or on different basis.

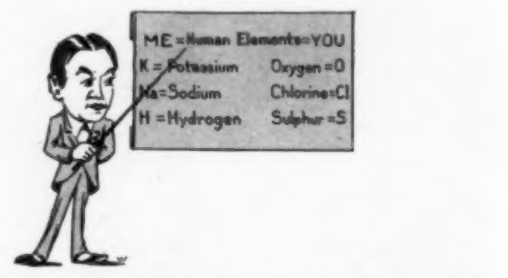
The foregoing has stressed the decidedly variable nature of co-ordination of control. Perhaps the best summary that can be made of the proper working together of administrative, financial, sales, executive, mechanical, chemical and automatic function is the statement that the inter-relation must not be overdone nor, on the other hand, too much neglected. In short, the "Golden Mean" of Aristotle is the safest formula. The past 2,000 years has provided us with no better solution to any control question.

Breaking in the NEW OPERATING MAN

By Louis Fenn Vogt
Works Manager, American Cyanamid Company Linden, N. J.

THIS QUESTION of breaking in the new operating man may be viewed from a number of angles. It seems to be largely a matter of personal opinion as to the ways and means of doing it rather than something well established by general agreement among plant men. Perhaps the best method has not yet been found; at least it must be conceded that conditions in the plant and organization will largely cover the procedure to be followed. Accordingly, these observations, based only on this writer's philosophy and experience, are presented for such value as they may have to others faced with similar problems under similar conditions.

From a plant operating viewpoint the human element could well head the list of chemical elements. In fact, the information to be had about the human element often



seems to be less definitely established than are the data concerning even the least known of the chemical elements.

The governing factors in the breaking-in of any operating man will include among others the type of job under consideration, the size of the organization, the product manufactured and, doubtless of most importance, the kind of man selected for the operating job relative to his past experience, his personality and his education.

Considering these governing factors in the order stated it is evident that the kind of operating job under consideration may include all berths up to and including that of the vice-president in charge of operations. For each station along the route from the first rung to the top of the ladder, there may be variations in the methods of breaking in the operating man. Yet there are some things common to all and these will be considered here.

The size of the organization determines whose duty it shall be to train the new man. The larger the organization, the less personal is the attention given to the individual on the part of the department heads and higher officials, and the more the new operating man

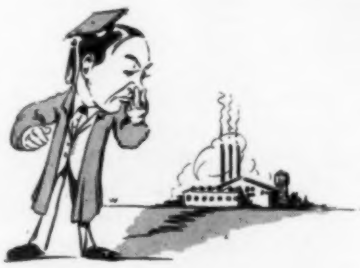
must rely on his own efforts with the help of his immediate superior and those about him.

The kind of products manufactured also has an influence. Some men are qualified by experience and personality to handle raw materials and men for large tonnage production, with vision as to output, equipment and costs. Others lack these qualifications and are entirely unsuited for mass production, yet they may be equally successful in the manufacture of products requiring unusual close control and a patient perseverance and persistence that compensate for low yields and high costs. The breaking in of the operating man presupposes earlier consideration of his capabilities but sometimes the suitability of a man is not evident until he is actually under fire. In other words the cut-and-try method must sometimes be used, in finding the right man to produce the right product.

Probably the most important factor of all is the kind of man selected for the job, more specifically his past experience, his personality and his education. Without due consideration to these, it does not matter much how an operating man is broken in.

The order of stating "experience," "personality" and "education" is intentional, for it represents their relative importance from a plant operating viewpoint. Some may urge that education should take precedence, but I believe that acquired experience and personality weigh heavier than earlier education in the training of most successful operating men.

There is something about the educational system for



technical men that does not quite meet the need in the preparation for operating positions. It may be a state of mind, the effect of too much devotion to study in the character-forming years of sixteen to twenty; but for some reason the brightest men in the graduating class seldom make good operating men and post-graduate students rarely have that something which is so necessary to successful production. These men attain success in research, in teaching and in many other lines, but they are rarely the type that "make the wheels go round." There are exceptions, of course.

Desirable operating habits and procedure may be cultivated in the operating man to best advantage when he has that intangible aggressive something in his make-up which for lack of a better description might be called the production or operating attitude of mind. It is that which makes him eager for training, makes him enjoy his work and makes him willing to put in long hours without complaint when needed. It will be helpful to learn the attitude of the new man as one of the very first steps of the breaking-in process.

In the case of an operator for a department of a chemical plant, it is good practice to see that the operating instructions and technical reports are studied before or soon after the start of the breaking-in. Even the obsolete reports and other "ancient history" are valuable since they may prevent mistakes and will often give a clearer picture of the development of the operation to its present status.

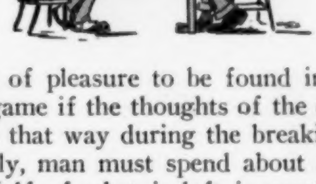
The new operating man should come from within the organization wherever this is possible. It sometimes happens, of course, that the right man for the job is

not available within the company. In this case it often helps to have the new man serve a few months in the chemical laboratory to familiarize himself with the products and to get acquainted with the organization, or he may serve for a time with the process development division or whatever the "trouble-shooting" department is called in that organization.

Theoretically the new operating man should always be broken in before the vacancy occurs, in order to insure against the plant being caught unprepared in an emergency. At the same time this makes it easier for the man ahead to advance. The breaking-in on several jobs or in more than one department broadens the man and adds to his value. In a diversified plant where some departments produce a few months out of the year, it is essential to train the operators for a number of positions.

The most common form of initiation, whether it be for a workman-operator of a furnace or filter press, a chief operator of a shift or an operating executive, is through service as an assistant to the man higher up. It is the easiest way but it is not always productive of the best results since the assistant may copy the methods of his superior to please him—faults and virtues alike. Among the finer points of the breaking-in process, applying to any operating man, is the matter of cultivating morale, enthusiasm for the work, and pride in the accomplishments of the department or the works or the company. This usually means a successful organization.

Plant operation is a game, which men play very much like a game of cards. It is a difficult, troublesome game, which some play only for money, but the best players like the game for the game itself. There are cards to play which come out in the deal and tricks may be won or lost on judgment and experience in playing the cards.



There is a lot of pleasure to be found in the work of the operating game if the thoughts of the operating man are directed in that way during the breaking-in process.

Unfortunately, man must spend about a third of his life asleep. Half of what is left is usually devoted to his work and if it could be generally checked up, it might be found that most of the fun in life comes from playing the game of work. There are few who are content in idleness. Stimulation of interest and pleasure in the accomplishment of work of the job, whatever it may be, is the best gift any of us can pass along to the new operating man.

Where
CONTROL OF QUALITY
Dominates
Manufacturing Operations

By C. A. Gillingham
Works Manager's Department,
National Carbon Company, Cleveland, Ohio

The manufacture of dry cells and of miscellaneous carbon products is an extremely complicated chemical engineering business. Until precise technical control entered this industry neither manufacturer nor user could count on the quality of products delivered. Now this situation has changed radically, for today, despite the manufacture of millions of units, there is a very high standard of quality and of uniformity of product maintained.

The organization which makes this result possible in one of the largest manufactories in the carbon business is highly suggestive of ways to solve similar problems in other branches of industry. Co-ordination of technical matters from raw material to finished product by means which work effectively with real economy in costs is described in this article by Mr. Gillingham, who is personally largely responsible for the highly successful scheme described.—The Editor.

AMERICAN industry, probably more than foreign industry, has for the past two decades recognized to a rapidly increasing degree the need for real quality in its products. This trend toward improved quality has been fostered by healthy competition, by the demand for truthful advertising, by increasing knowledge on the part of the consumer regarding his raw materials, and by the increased use of purchase specifications by the government and private industry.

The National Carbon Company, Inc., has gradually developed an organization whose prime function is to cope with this increasing demand for quality. The Company has a number of widely scattered factories producing a variety of products including dry batteries of all types, carbon brushes, arc carbons, large and small carbon electrodes for electrolytic and electrothermic uses, arc lamps, radio sets, etc. The operation of all factories is directed by a central works manager's department located in Cleveland. This department has six divisions, each charged with a particular phase of factory operation. One of these divisions is devoted entirely to product quality.

The quality division head is responsible to the works manager. He is supported by a corps of experts, each covering a particular product or group of products. This division has its own quota of stenographers, clerks, and draftsmen necessary to make it a complete operating unit. All plant superintendents are responsible to the quality division on all quality phases of their factories' operation. This division's function is to maintain the quality and uniformity of all the Company's products, and to watch for and apply any new developments which may become available for improving them.

The company has an extensive research laboratory working continuously to develop new products and to improve those now being manufactured by the Company. This research laboratory is, from a managerial standpoint, entirely independent of the quality division of the works manager's department. Its recommendations are, however, made to the quality division. They are there developed as to their manufacturing aspects and when complete, presented to one of a series of product committees for consideration. There are several of these committees, each pertaining to one particular product or to a group of similar products. Each committee is made up of individuals appointed by the works manager, who are considered best qualified by experience to act upon such matters. Wherever possible the committee membership includes representatives from all plants manufacturing the product with which it is concerned. The chairmanship of all these committees is held by the head of the quality division. The committee's secretary is in each case the member of the quality division who is particularly experienced in the product with regard to which the committee functions. The committee's action on all matters is subject to the approval of the works manager before becoming effective.

This committee plan has been found to work very

smoothly and has the advantage of ensuring consideration of laboratory recommendations by a well qualified group. It has been found also that the meetings of these committees have developed a co-operative spirit among the plants and between the plants and the management which has been very effective in producing a smoothly operating organization. Factory representation on these committees also does much to smooth the way when new products and new improvements are introduced into production. The committee plan spreads the responsibility for product changes over all members of the committee and this sometimes facilitates reaching decisions which in the case of individual responsibility might be seriously delayed through fear of consequences in the event of error.

ACTIVE maintenance of quality and uniformity at each plant is accomplished through works laboratories, one of which is located at each factory. The operation of these works laboratories is a responsibility of the plant superintendent, but the activities in which they indulge and the manner in which these activities are carried out are supervised and controlled by the quality division of the works manager's department. Each works laboratory inspects and tests all incoming materials entering into manufacture, supervises quality factors in plant processes, inspects product both in process and after completion, maintains a general oversight of workmanship, housekeeping, etc., and sees that correct manufacturing procedures are followed.

In each group of plants manufacturing a particular product there is one works laboratory specially equipped for such experimental work as is necessary in developing the factory application of research laboratory recommendations. These process engineering units, as they are called, also originate many new ideas which may be further developed either there or in the research laboratory as may seem most appropriate. The works manager's quality division supervises the work done by these process engineering units. Each experimental job is carried out on a special appropriation approved by the works manager's department and all reports and recommendations are made to the quality division.

EXPERIENCE has shown beyond question that one of the factors in the control of quality and uniformity is the maintenance of proper and uniform methods of manufacture. It is a natural function of the quality division, therefore, to prepare and issue to the factories complete specifications, known as manufacturing instructions, covering the methods to be followed in all manufacturing operations, listing inspection requirements and specifying methods of inspection, giving composition of mixes, solutions, etc., and listing the specifications which the finished product must meet. These manufacturing instructions are issued in loose leaf form and locked in substantial binders which prevents scattering and loss of instruction sheets and ensures safe keeping and ready reference. Each book of instructions is charged personally to an individual, whose responsibility it is to keep it in good condition and to prevent its getting into unauthorized hands. As changes are made, revisions are sent out in the form of new pages, accompanied by an acknowledgment slip, which must be signed by the recipient and returned for record along with the obsolete pages replaced by the revised ones. This has been found quite necessary in order to ensure all sets of instructions being kept up-to-date and free of obsolete information. The acknowledgment slips serve to show that changes in instructions have been received and noted by interested parties. The superintendent is held responsible for the proper application of these manufacturing instructions in his plant, and the works laboratory under him makes periodical checks of factory procedures to determine proper compliance with them.

ANOTHER phase in the maintenance of quality and allied with the manufacturing instructions is the preparation and issue by the quality division of specifications for raw materials. Practically all materials entering into the company's products are purchased on so-called "RM" specifications. These are issued in a manner very similar to the manufacturing instructions. Books of "RM" specifications are placed in the hands of all purchasing agents, receiving departments, and works laboratories. The purchasing departments use these specifications in ordering materials and in placing contracts. It is the responsibility of the works laboratory in each plant to check all incoming materials against these specifications, and many carloads of material are rejected each year because of failure to comply. In preparing these specifications the policy pursued is to make them as liberal as possible without jeopardizing the product in which the material is to be used. This ensures diversity of sources of supply and minimum cost, while at the same time maintaining quality of product.

A necessary adjunct to the raw material specifications is a series of instructions on methods of testing. These are worked out by the research laboratory and edited and issued by the quality division of the works manager's department. All works laboratories are governed by these works control instructions in all chemical and physical tests made by them.

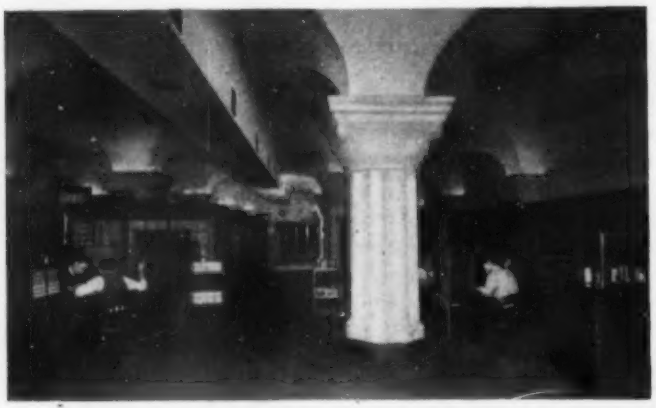
The Company's experience in the past has repeatedly shown that the worst slips in quality of product have resulted from ill considered changes in materials or processes. Safeguards have therefore been established to ensure proper consideration of all such changes. No changes are allowed except upon authorization from the works manager's department and this is forthcoming only after the question has been considered carefully by the appropriate product committee (as previously described) and its recommendation approved by the works manager. A minimum number of changes, consistent with necessary progress, results in a stability in manufacture which yields low costs, minimum scrap and waste, and maximum uniformity of product.

ONE of the important tools for the control of quality is the close study of the reject and scrap records of the various products. It has been fairly well established that the plant which shows the lowest scrap record will usually be the producer of the best product, both as to appearance and electrical or physical properties. It has also been found that the tightening up of inspection requirements, while at first increasing rejections and scrap, will ultimately result in a marked reduction. This is the natural result of stimulated effort to keep scrap down and the increased skill of workers and supervisors which is naturally developed thereby.

The quality division has instituted a system of scrap records which in the principal products show the various items of rejected and scrapped material in great detail.

By grouping the various items according to their disposition and keeping cost records on the disposition of the different groups, it has been possible to show the actual loss to the Company of each item of rejects and scrap each month. An allocation of the various items against the departments responsible for the fault, thus showing a total for the loss for which each department is responsible, has been a wonderful incentive toward scrap loss reduction.

This has been further stimulated by the preparation



Dry Cell Testing Laboratory
Testing capacity is 100,000 tests simultaneously, at constant temperature and constant humidity. Tests are made on the product from the company's factories, competitors' products, and experimental material.

by the quality division of monthly reports comparing the scrap losses in detail at all plants manufacturing the same class of product. These reports are distributed to the various plant superintendents and to the management. The success of the whole scheme hinges absolutely on the standardization at all plants of rejection limits and inspection standards through very complete manufacturing instructions. The introduction of the system described has made possible unbelievable reductions in scrap losses, and literally saved the Company hundreds of thousands of dollars in the last few years.

Closely akin to scrap reduction is plant cleanliness and neatness which communicates a spirit to the workers and supervisors which reflects in better workmanship and better product. It attracts better help and tends to hold experienced workers. The quality division fosters good housekeeping and neatness in every way possible.

To obtain a measure of the gross result of all the means used to maintain quality, the output of each factory is sampled daily for testing. The daily samples are in most cases composited for a week and the weekly sample sent to a central testing laboratory not connected with any plant. There the tests are conducted without any possibility of bias and under ideal conditions. Tests on dry batteries, for instance, are conducted in a large constant temperature, constant humidity room by automatically controlled contact making equipment at the rate of several hundred thousand tests annually. Experimental products are also tested in this same laboratory.

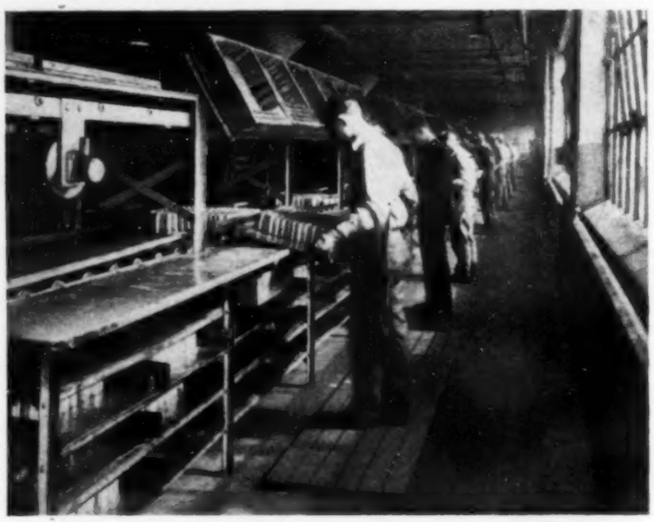
The test results are reported to the quality division and to the works whose product they represent. The quality division prepares and issues a monthly report comparing the performance of the product of all the plants. This has engendered a friendly rivalry among the plants and formed a very effective incentive to improve quality and particularly uniformity of product.

A record of all complaints also comes to the quality division and these are recorded and analyzed and related to sales billings. This record, if effectively worked out, forms a valuable means of keeping in touch with the reception given the Company's products by the trade in general.

In order to keep abreast or ahead of competition, the products of leading competitors are regularly purchased on the open market and subjected to the same tests as the Company's own products. These tests are, of course, also made at the central testing laboratory.

Regular and frequent visits are made by the men of the quality division to all factories to keep in touch with their manufacturing conditions and to aid in solving factory quality problems.

The present status of the quality division in the National Carbon Company's organization is the culmination of a gradual development, the general plan of which



Manufacturing Inspection of Dry Cells
This inspection is made after assembly before the wax seal is applied. Trays of cells are brought to the inspectors on the lower conveyor. After inspection the full trays are placed on the shelves below the table from which point they are removed by manufacturing operatives on the opposite side of the conveyor for further processing. Empty trays are returned by the upper conveyor.

was conceived about ten years ago. The period of its growth has been marked by steady progress of a major order. The cost of operating the division has been insignificant compared with the advantages gained and savings accomplished.

Temperature and Humidity Control in Rubber Testing

The physical testing committee of the rubber division, American Chemical Society, through its research associate, F. E. Rupert, has conducted a series of tests at the Bureau of Standards to determine the effect of temperature and humidity control in rubber testing, reports the *Technical News Bulletin* of the Bureau.

The part of the investigation of samples subsequent to vulcanization proved that variations in temperature which may occur from day to day in an uncontrolled testing room may affect the physical tests to the same extent as a 25 to 40 per cent change in time of cure. The relative humidity affects the results in only a minor degree.

An extension of this investigation is now in progress at the Bureau.

ACCIDENT PREVENTION

Demands Control of Human Factor

By STANLEY H. KERSHAW
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REPORTS available from industrial chemical plants indicate that a large percentage of accident delays and failures in process operations are due to failures of the human factor rather than to the processes.

Assuming this fact, any study toward increased safety control in process operation in a particular plant should be a broad one. It should include the entire field of possible human failures in the plant and the entire field of possible mechanical safeguards for all operating processes.

The provision of mechanical safeguards for operating processes should of course go back, when possible, to plant construction. It is well known that there has been, within a comparatively few years, a great advancement in the study and the application of safety provisions in plant construction within the chemical industry. Many forces have been aiding in this development. A number of the larger casualty companies have specialized departments and trained investigators whose business it is to assist in the study and the revision of plans in the interest of improved safety control. The National Safety Council maintains sources of information through its chemical section, a library and a staff of engineers. Then there are such departments of government as the Bureau of Mines, Bureau of Standards, and the Department of Labor, equipped to give expert advice. Also, a number of state industrial accident commissions are active in this field of advance safety aid. The American Standards Association has done much to produce national safety codes and make them available to the industrial world.

VENTILATION is a most important provision for both the chemical laboratory and the plant. One company, in order to insure emergency ventilation, equipped their main operating room with an airplane propellor and electric motor in an opening in each end wall which could change the air within two minutes.

The best of illumination both in the laboratory and the plant is a good investment. Recent investigations show that better lighting often has increased the efficiency of plant workers by 20 per cent or more. This results in lessened fatigue and hence lessened accident possibilities.

Good housekeeping is an important safety factor in a chemical plant. The chief problem here often is the proper disposal of chemical refuse. The plant that has not been following a consistent program of good housekeeping often can recover enough of waste materials to pay for the labor cost of a thorough clean-up. Proper receptacles, bins or tanks for refuse is an important part of any good housekeeping program. It is good practice to reclaim and clean at the time of their disposal all materials that are worth storage room. The providing of bins for scrap iron is a good practice. Convenient metal receptacles with covers, in different parts of the plant, always aid in the establishment of good housekeeping habits. The prompt removal of discarded equipment and temporary scaffolds will aid in the reduction of common injuries. "Clean-up gangs" regularly at work are more often than not a good plant investment.

Some laboratories follow the practice of painting various water and gas pipes in different conspicuous colors so that they may be readily distinguished one from another. This is carried out on a larger scale for the process piping in some plants.

FIRE fighting equipment that is adapted to the chemical hazards and that is frequently inspected, of course, is a necessary safety control feature. Water showers, well located and easily operated, are good protection for chemical workers who are exposed to the danger of spills, sprays or splashes of acid and need to deluge themselves with water quickly.

A complete program of safety work in a chemical plant must include all operations. This of course would include the proper mechanical protection of all machinery, free passageways, good ladders and stairways, trucks adapted to particular needs, provision for the economical and safe storage of materials. Since many chemical processes demand an exceptional degree of mechanical maintenance, this gives importance to a program of systematic regularity in maintenance and safety inspections.

Safety control demands a complete understanding of all plant processes, as related to the health of the workers. This study should take into consideration all of the processes and all chemical compounds that have a part in them.

When an inspector visited one plant, for example, the manager reported that working conditions were entirely favorable. But it was found on inquiry that the labor turnover was 40 per cent and that an examination of 20 of the employees revealed 18 with symptoms of poisoning.

Proper control for safety is largely a problem of intelligent plant supervision. High efficiency of production and accident reduction go together. Because of the introduction of out-of-the-ordinary hazards, the chemical plant usually demands a much higher degree of supervision and co-operation on the part of management and workers than is demanded by the average industrial plant.

The human element, of course, is a large factor. It

is a growing practice in chemical plants to approach the human problem through an initial physical examination of all employees. To be thorough, such examinations must be followed up periodically. One plant, in beginning such a program found it advisable to group their employees as to frequency of time for repetition of physical examinations according to their physicial conditions and the hazards of their occupations.

Safety control, as related to the human element, demands a well planned and continuous educational program. This program of course should include all of the ordinary hazards of the plant. One large company, to determine the hazards, made a careful study of their accident records over a period of years. They selected the most common of these hazards and then prepared a series of posters.

The average chemical plant has hazards which are commonly supposed to be difficult to guard against through educational instruction. However, plant managers testify that workers easily can be taught a certain amount of chemistry, when the terms of instruction are simplified. This simplification consists largely in what has been called "appealing to the imagination." In the application of this principle, one plant has ceased to talk about "missile hazards." Instead, they call them "widow makers."

The workmen should be taught to recognize the three special hazards of the chemical industry, namely, vapors harmful to breathe, corrosive liquids that may burn the skin, possible fires and explosions. The plant posters should feature and warn against these particular hazards.

It should be the duty of the foremen to train their men to a realization of the risk which they assume in the handling of poisonous and corrosive substances and explosives. In many chemical plants, the foremen also must educate their men against exposure to complicated and dangerous machinery. They must take especial care to train their new men in a realization of the special dangers in the many tasks they are asked to perform.

One of the well known hazards of the industry is the danger of explosions from containers of acids. Drums when in storage should be frequently inspected, and when emptied they should be promptly gotten rid of, if they cannot be freed of their contents by washing or steaming.

Sometimes very simple practices have removed explosion hazards. For example a plant safety engineer, following two explosions of dry sulphur dust, suggested the wetting of the sulphur, while being handled, as a preventative. Investigation indicated that such wetting would not be injurious; and there was devised a simple sprinkler to wet the sulphur while it was being unloaded. Since that time they have never experienced another such explosion.

Many companies have rules which prohibit a workman entering empty acid tanks unless absolutely unavoidable. When it is found absolutely necessary to place a man in such a tank, it should first be provided with at least two openings to fresh air, one at the top and one at or near the bottom. The manhole should not be less than 24 inches across. All chemical pipe lines leading to the tank should be "dead-ended" by removing a section from each of them. The man should be provided with a safety belt, and with an assistant outside the tank to give warning if anything should go wrong. The wearing of a gas mask of the fresh air supply or canister type by the man who enters is insisted upon in all cases by some companies. An adequate supply of gas masks, with thorough instruction on how to use them, should form an important part of the plant equipment.

Assuming that it may be of interest, we have tabulated the relative accident frequency and accident severity rates of the seven different divisions of chemical manufacturers who reported for the years 1926 and 1927 to the National Safety Council.

The paint and varnish manufacturing plants, as a group, show the lowest average accident frequency rates. The record of this group is an average of 8.37 lost-time accidents per one million man-hours worked. Eight plants reported in this group. One plant, with an average of 44 employees who worked 105,456 hours, had no lost-time accident during the two-year period. The largest plant of the group, as a result of 13,432,009 hours of work by 5,597 employees had a lost-time frequency rate of only 2.53 lost-time accidents for one million man-hours worked. The plant in this group with the highest accident frequency rate employed an average of 138 men, who worked a total of 339,533 hours. They had an accident frequency rate of 23.56.

Following is the relative accident frequency rates for all of the seven groups:

Paint and Varnish Manufacturing	8.37
Dye Manufacturing	16.79
Acid Manufacturing	17.36
Explosive Manufacturing	17.83
Smelting and Copper Refining	22.51
Coal Tar Distillers	45.58
Soap Manufacturing	46.11
Average of the 7 groups	19.12

The second tabulation which we have worked out relates to the relative accident severity rate for the same seven groups. In this, the coal tar distillers show the best average record. That is, they show the least number of days lost per 1,000 man-hours worked. In this group seven different manufacturing plants reported to the National Safety Council. Two of these plants had no lost-time accidents, hence a perfect severity accident record. One of these plants employed 25 men on an average, who worked a total of 66,773 hours; the other plant had an average of 22 employees, who worked a total of 55,350 hours. The plant which ranked seventh in the list had an average of 18 employees, who worked a total of 46,718 hours. This plant had a total of five accidents, which resulted in a loss of 24 working days. Their severity rate thus was .51.

The relative rank, in accident severity rates, for the seven groups was as follows:

Coal Tar Distillers	.41
Soap Manufacturing	.85
Paint and Varnish Manufacturing	.50
Smelting and Copper Refining	2.97
Dye Manufacturing	3.06
Acid Manufacturing	3.13
Explosive Manufacturing	3.68
Average	2.35

The 143 chemical establishments which reported in 1927 to the National Safety Council are as follows: 8 Acid Manufacturing; 7 Coal Tar Distillers; 6 Dye Manufacturing; 16 Explosive Manufacturing; 8 Paint and Varnish Manufacturing; 13 Smelting and Copper Refining; 9 Soap Manufacturing; 76 miscellaneous chemical plants.

A Completely AUTOMATIC PLANT Makes Carburetted Water Gas

By R. S. McBride
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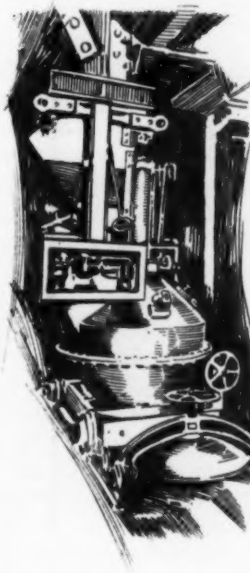
CARBURETTED water-gas manufacture can now be carried on by a completely automatic plant. This seemingly simple reaction of coke and steam is in reality a very complicated and difficultly controllable chemical-engineering process. And yet, careful studies of process reactions and highly ingenious mechanical equipment have been combined to produce control facilities of unusual effectiveness. By applying in any plant all of these unit controls one has a combination of unusual completeness in its automatic functioning; and yet one needs to utilize for such a set-up no device that has not already had thorough industrial demonstration as a practical machine.

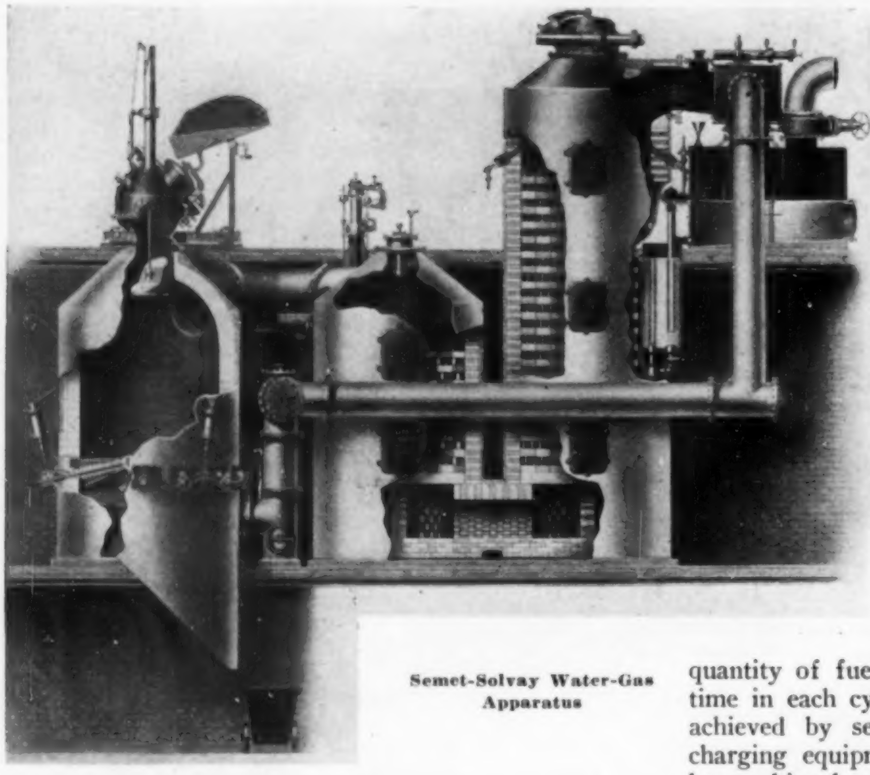
The simple theory of carburetted-water-gas production requires alternate passage of steam and of air blast over an incandescent fuel bed of coal or coke with the introduction of oil on highly heated checker brick during the period when the steam-coke reaction is in progress. In the early days of water-gas making the machinery for carrying out this operation on a commercial scale was hardly more complicated than the above description would imply. The water-gas maker went personally from valve to valve, turning on and turning off in appropriate order the steam, the oil, the air blast, and opening or closing the various gas valves, stack valves, and other operating parts. With increasing size of machines it was a logical next step that these valves should be controlled by hydraulic units. And it was only a short step further to the point at which the controls on the hydraulic devices were grouped together so that the gas maker could reach them all and operate them in turn with a minimum of delay. Then came the automatic man, a most ingenious robot, devised more or less simultaneously by several builders of water-gas equipment to carry out the mechanical function of valve opening and closing.

WITH THE INTRODUCTION of automatic valve manipulation much time was saved and it became possible for one skilled gas maker to tend more than one set. However, this and the contemporary growth in the desired sizes of machines introduced large complications in gas making. Because this operation involves the handling of such huge volumes of air, steam, and gas, and must be carried out at such high temperatures, it is possible that without very precise control some part of a big machine may within a few minutes get hundreds of degrees too hot or too cold, with consequent damage to yields and efficiencies.


Automatic Charger

It no longer sufficed at such a stage in the development of the art to take steam, air blast, and oil from the various supply lines at uncontrolled pressures and in unmetered volumes. More precise functioning of the machine was essential if production capacity was to be maintained and high fuel efficiencies for both coke and oil were to be had. As a result, uniformity in steam pressure and of blast pressure was arranged, a result made possible by well known control devices; and now the volume of each of these supplies is also controlled in the most modern machines so as to be constant and independent of the fire cleanliness.

The steam for a typical water-gas set is generally taken from a low-pressure accumulator. The steam for this unit comes principally from the exhaust of steam-driven blowers, pumps, and other auxiliaries used in water-gas manufacture. In order that the steam supply in the accumulator will always be sufficient a high-pressure steam line is run to it from the main steam header of the plant, and an automatic valve in this line opens whenever the accumulator pressure drops below a predetermined point. The outlet steam from the accumulator is also automatically controlled as to pressure



Semet-Solvay Water-Gas Apparatus

mechanism opens or closes by an appropriate amount a butterfly valve in the supply line.

INTRODUCTION of solid fuel into the generator was formerly accomplished by opening the charging door and dropping fuel onto the fire. This operation was carried out at intervals appropriate to the size and speed of operation of the set, usually at least twice an hour. Invariably it took several minutes to take the machine off the line, open the charging door, introduce the fuel, close the charging door, and resume the normal rate of gas making. Furthermore, this intermittent introduction of large quantities of fuel chilled the fire and uniform conditions of gas-making could not be maintained between charging times. Ideal conditions require the introduction of a small quantity of fuel every few minutes at the appropriate time in each cycle of operations. This ideal has been achieved by several companies who make automatic charging equipment. The coal or coke is brought to be machine by belt or chute which automatically feeds into the automatic scale hopper for weighing each charge. The weighing hopper discharges at the appropriate time in the cycle into the charging hopper which is directly above the generator. Then at a later time in the cycle the fuel is dropped from the charging hopper onto the fire, being distributed or directed to the desired point by a spreading device which is lowered into the top of the machine. This spreader serves also as the lower gate of the charging hopper. The introduction of the solid fuel usually takes place during the "down steam" part of the run; hence any fines in the fuel are carried down into the fire and are less likely to be blown over into the carburetter during the blast and up-steam run of the next gas-making cycle. Thus maintenance of clean checker brick is an incidental advantage obtained. The major advantage is, however, maintenance of constant fire level and entire elimination of the interruption in gas-making for fuel introduction.

In the case of a twelve-foot water-gas generator, making from three to five million cubic feet of gas per 24 hours, the generator necessarily consumes from 50 to 75 tons of coal or coke per day. The ash from this fuel must, of course, be removed from the generator at appropriate intervals, and this is no easy job to carry out by hand, since much of the ash becomes fused and may adhere firmly to the side wall of the machine. Furthermore, the loss of time incident to hand cleaning of a machine one or two times each day is considerable, often making a total of two to four hours out of the twenty-four.

AUTOMATIC ash removal was, hence, a much-desired improvement; the companies who have successfully solved this problem have all found cordial welcome for their equipment. In all devices developed for this work the ash is crushed by the grate-discharge mechanism so that it drops through the grates and accumulates in the bottom of the set from which it can be quickly dumped at stated intervals during the day.

It is now proposed by one of the companies making

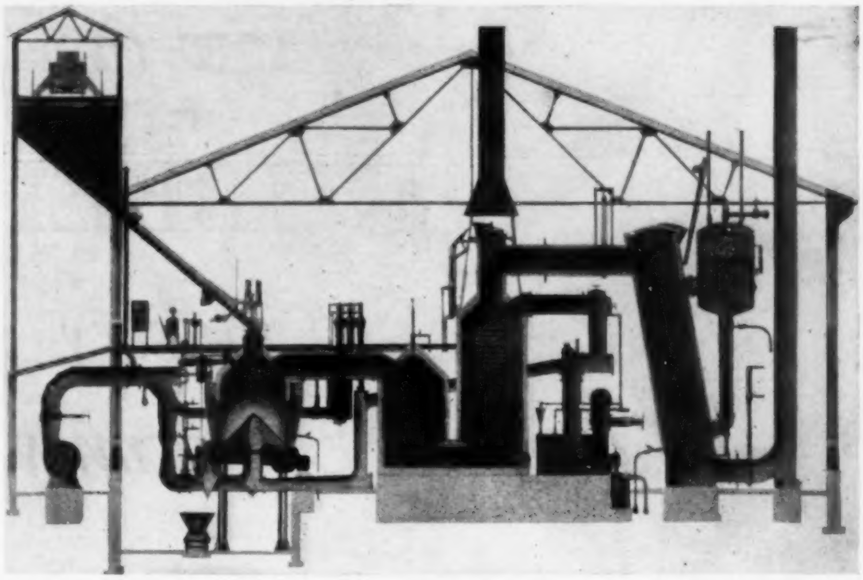
so that an excess pressure in the accumulator will not build up the steam pressure in the low-pressure header in the generator house. Excess steam is relieved at or ahead of the accumulator by automatic relief valves.

In most water-gas plants, the air blast is generated by electric or steam-driven blowers which work within rather wide pressure ranges. A novel type of device for more precise control of blast pressures has been developed by the General Electric Company at the works of the Baltimore Consolidated Gas, Electric Light and Power Company. This unit functions on a group of steam-turbine-driven blowers to give very constant blast pressure, first by controlling the blower speed, and secondly by bleeding air out of the system whenever the air requirements are so low that slowing down the blowers does not suffice to control blast line pressures. This last feature of control has proven to have an additional advantage in preventing the howling of the blower during operation at such light loads that the air pressure builds up and breaks back through the blower.

IF THE FIRE in the water-gas generator were always constant in condition, as is theoretically desirable, the volume of air and of steam taken during blast and make would be held constant by merely controlling the pressure as above described. But even with the best machine operation there is a wide fluctuation in the condition of the fire between the periods of ash removal and variation in fire-bed resistance is also brought about by changes in fuel size. Hence, it has been found desirable to introduce a volume-control unit on both air blast and steam lines so that during the minutes of "blast" and the minutes of "make" there may be as nearly as possible constant supplies, regardless of clinker or fuel conditions in the generator. At the Baltimore plant this result has been accomplished by introducing in each of these two lines an orifice, Venturi, or Pitot-tube unit. Connections are taken from each side of this measuring device to a diaphragm governor. When the pressure drop across the meter is too high or too low this diaphragm

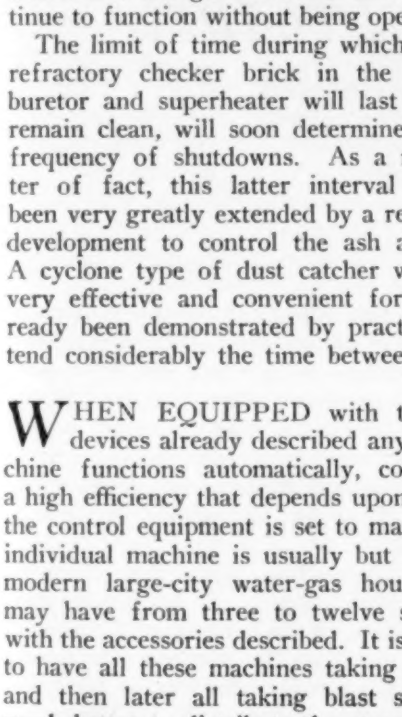
automatic ash-sluicing equipment that even the brief opening of the machine required for this dumping of the ash shall be eliminated. It is planned to try out the ash-handling equipment which has been successful for ash removal from boilers in a modified form on the hopper bottom of a water-gas set which has an automatic clinkering device. If, as seems almost certain to be the case, the ash-sluicing equipment proves to be effective in appropriately modified form, there will then be practically no limit to the time during which a water-gas machine can continue to function without being opened.

The limit of time during which the refractory checker brick in the carburetor and superheater will last and remain clean, will soon determine the frequency of shutdowns. As a matter of fact, this latter interval has been very greatly extended by a recent development to control the ash and fuel "blow-over." A cyclone type of dust catcher which has been found very effective and convenient for this purpose has already been demonstrated by practical operations to extend considerably the time between recheckerings.



U. G. I. Mechanical Generator for Carburetted Water Gas

WHEN EQUIPPED with the numerous control devices already described any single water-gas machine functions automatically, continuously, and with a high efficiency that depends upon the conditions which the control equipment is set to maintain. However, the individual machine is usually but one of several in the modern large-city water-gas house. A typical house may have from three to twelve such generators, each with the accessories described. It is obviously undesirable to have all these machines taking steam simultaneously and then later all taking blast simultaneously. It is much better to distribute the steam load, the blast load, and the production of the machines over different intervals of time so that the total blast or the total steam taken will be substantially constant throughout a long period of uniform gas production. This requires merely an appropriate synchronization of the various machines, so that the several cycles may be timed to avoid undue overlap of similar operations on the part of different machines. Synchronizing units for this purpose have been developed by several water-gas construction companies and are already in successful, though still somewhat experimental stages of commercial operation.



Howard Automatic Charger

This synchronization appears to be the last step required to make the mechanical functions of the water-gas house continuous and automatic. However, there remain still unsolved the question of precise temperature and chemical control within the set. Such control is, however, not despaired of. The company in Baltimore to which reference has already been made is now operating its large base-load sets with continuous recording pyrometers located at three points, the top of the carburetter, the base of the superheater, and the top of the superheater. The gas maker on the operating floor by noting these three temperatures can determine within very narrow limits just what conditions are developing in each set. He is thereby enabled to anticipate trouble and to correct any trends away from normal operations before they result in serious disturbances of machine functioning.

NOW the main job of the water-gas maker in a well-equipped plant is to interpret automatic recording and indicating devices rather than to control the mechanical functioning of the machine itself. The records which can be made available to an experienced gas maker are so complete and the mechanism to be used is so fully developed, that if he be skilled in his interpretation it is possible to maintain over weeks at a stretch almost absolutely uniform conditions in each part of the gas-making unit. Thus there is achieved that ideal of chemical engineering operation, an uninterrupted and highly efficient machine operation with the efficiencies and yields limited only by the inadequacy of our present engineering knowledge as how to design and to build. In coming so close to the operating ideal, the gas engineers have certainly set a very fine standard of plant control which all other groups of chemical engineers will do well to study and emulate, within the possibilities offered by their operating procedures.

Grateful acknowledgment is made by the author to John H. Wolfe, Superintendent of the Consolidated Gas, Electric Light and Power Company of Baltimore, whose wide experience and cordial co-operation have greatly aided in the accurate preparation of this view of modern water-gas practice.

How the

RUBBER

Industry

Maintains Uniformity of Product

By R. W. Moorhouse

Manager, Chemical Engineering Division
The Goodyear Tire and Rubber Company
Akron, Ohio

CONTROL of operations in the rubber industry is at this date almost entirely manual and laboratory. Lack of uniformity in raw materials has forced the use of close laboratory control of each batch of material put up, with decisions based on the experience of the organization.

Development in the industry has been along the lines of large capacity and labor-saving machinery, rather than of automatically controlled equipment. Demand for increased production naturally centered attention on the tools, while the old methods of controlling quality and operation were more slowly changed.

The rubber industry may be divided into several groups, according to the type of product, as follows: (1) tires and tubes, (2) mechanical goods, (3) boots and shoes, (4) sundries and (5) reclaimed rubber. Reclaiming is properly included since not only does it deal with material both produced by and used in the industry, but it uses similar equipment and unit processes.

In all of the groups of the industry, there are several type operations. The details of each step, and the degree to which the material is processed, vary with the ultimate product. These unit operations may be listed as (a) selection and blending of raw materials, (b) compounding batches, (c) mixing and milling, (d) calendering and tubing, (e) assembling, (f) curing and (g) finishing and inspection.

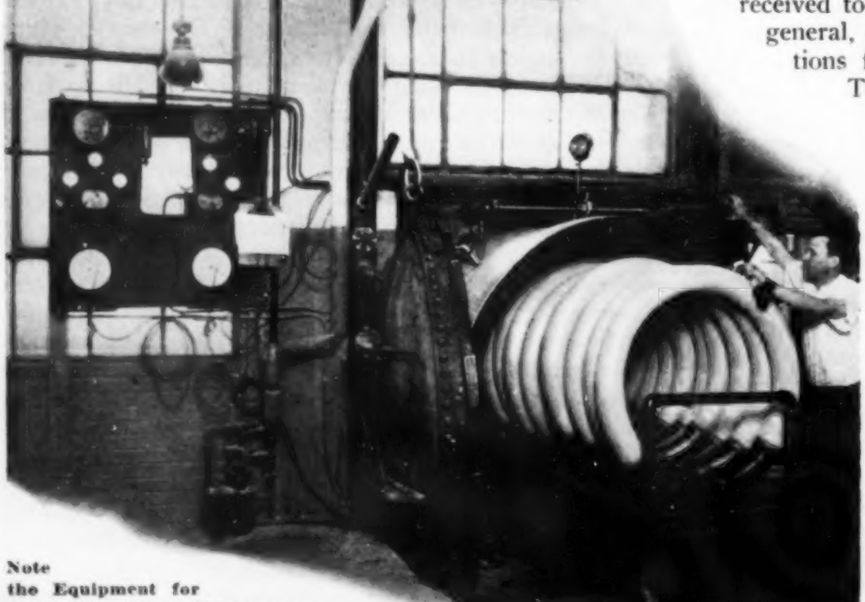
Selection and Blending—The basic raw material, rubber, varies in color, amount of foreign matter, plasticity, curing qualities, etc., according to the source. Large differences, as much as 300 per cent (in tensile strength, for example), exist between lots of the same commercial grade of crude rubber (R. P. Dinsmore, *India Rubber World*, Vol. 79, No. 6, p. 77). There is even greater variation between wild and plantation rubber.

Having purchased the crude, he must blend the lots as received to get as uniform batches as possible. In general, this is done by physical mixing of portions from four or five consignments.

The slabbed rubber is sampled as it is placed on a conveyor, the sample conveyed by pneumatic tube to the laboratory, and the control test finished and reported to the supervision by the time the conveyor delivers the slabs to the compound rooms. By this time the slab will have been air-cooled, and can be handled either directly into compounded batches, or onto the stock racks.

Other materials than rubber are bought on specifications so set that the variation is within safe limits. Laboratory tests of manually taken samples insure the quality, while the use of specifications places the burden of control on the vendor.

Compounding—Under this head come the treatment and preparation



Note the Equipment for Controlling Time, Temperature and Pressure in Mandrel-Cure of Tubes

of loading and reinforcing materials, the weighing out of specified amounts of each component of a batch, and the checking of each box made up.

Particle size is an important factor in the behavior of a pigment in a rubber mix. There is an ideal size for each pigment, since each has a definite function in the mix. Hence screening to a definite maximum size is used.

AUTOMATIC scales can be used in weighing amounts of material for each batch, but the flexibility and cheapness of the standard indicating beam scale has made its use almost universal.

All batches are check-weighed as they leave the compound room to be milled. While at present a weigher is stationed at an indicating scale to reject off-weight batches, it is possible that an automatic scale will be used to sort out these batches.

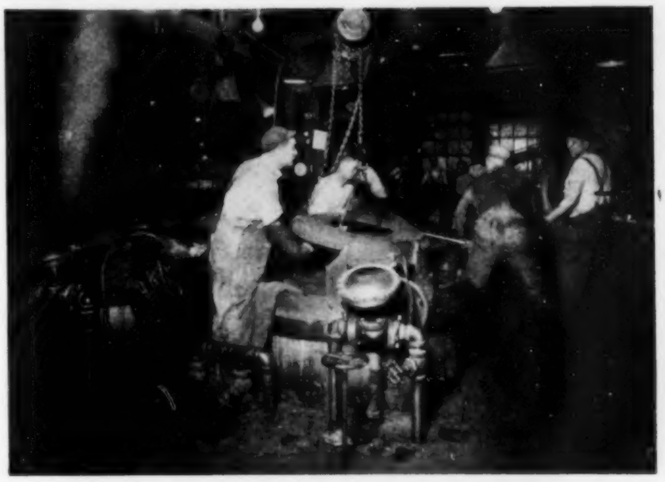
Distribution of compounded batches to the mixing mills is done by men and trucks or by conveyor. In either case men are required to control the work. Automatic control of distribution of as many different compounds as are now simultaneously run involves quite complicated equipment, the cost of which exceeds the small saving in labor from its use.

Milling and Mixing—Each batch of compounded stock, consisting sometimes of as many as six or seven components, must be mixed according to a definite milling specification. The order in which the ingredients are added to the mill or mixer, the time interval and manner of working between each addition, and the setting and temperature of the mill rolls are all fixed for a particular formula. Actual test runs, varied at will in the search for the best conditions, have been made to check the effect of each factor, and the product of each tested in the laboratory.

While actual conditions on the mill or in the mixer can be and are specified, attainment of them is left to the operator and the supervision. With the exception of temperature, no automatic controls have been developed. It is doubtful whether the variety of compounds run in a given plant will permit economical automatic control.

Temperature control, however, has advanced considerably. Formerly, mill rolls were controlled by varying the amount of water by regulating the control valves, as required by readings on surface temperature indicators. Pressure controllers have been used to insure constancy of flow.

THE temperature of the roll varies over a definite range from start to finish of a mixing, so that no real control in the sense of reducing variations is obtained. (R. W. Moorehouse, *India Rubber World*, Vol. 79, No. 6, p. 56.) Control of the flow from minute to minute, to correspond to the variations in temperature, has been obtained by a thermostatic valve, the expansion element of which is placed in the waste cooling water, the valve operating on the water supply. This method of control has maintained a 5 deg. F. range on a mill roll and has moreover saved 50 per cent of the water over the constant flow obtained with a pressure controller. The same saving in water may be obtained with a controller expansion bulb in a shoe on the roll surface, but the range of temperature is about 10 deg. F. The risk of damage to the equipment is very great in this case, so that it is seldom used on mills. Electrically operated



Control Panel and Valves for Tire Vulcanization

controllers, using thermocouples on the roll or in the water, perform well but are expensive.

It is conceivable that an automatic timing device may be used to regulate the amount of water to anticipate the temperature variations now found in milling.

Calendering and Tubing—In tires, there are two forms in which the rubber stock is served to the tire builder. One consists of the fabric of cotton coated and impregnated with the rubber stock for the carcass of the tire. The other consists of the stock alone, shaped to form the tread and sidewall of the finished tire. The carcass stock is made by calendering. The fabric, square woven, twilled, or of any other weave desired, is warmed and run through one bite of a three-roll calender, to the other bite of which is fed the strip of warm, plastic stock at an automatically controlled temperature. The stock carried around the middle of the roll is "frictioned" into the fabric or coated onto it. For proper working of the stock into the fabric, there is a certain roll temperature for each stock.

VARIATION in weight of stock per square foot of fabric must not occur, for then the maker either uses too little and produces a poor article, or he uses too much and loses money. It has been estimated that the losses from a variation of one one-thousandth of an inch in thickness will run into several million dollars annually at present production rates and rubber prices. An accurate measure of the thickness of the carcass stock must therefore be used constantly.

There are two types of thickness indicators in use today, neither of which automatically controls thickness. One depends upon the change in capacity of a plate condenser when the rubber coating passing between the plates varies in thickness. The other operates through the change in reluctance in a magnetic circuit set up with the roll and the magnet of the instrument riding on the rubber layer on the roll. Variations in rubber thickness cause changes in the reluctance, which are converted to read directly as changes in thickness.

Tread stock is calendered or shaped in a four roll calender, the fourth roll being cut of such a shape as to give the desired cross-section of tread. Feed of stock to the calender is continuous, as described above under feed mills. Changes in rate of feed are made by hand-resetting of the knives at the mill, as the lineal speed of the conveyor and the mill roll surface must be constant. The tread leaving the calender passes over a contin ously indicating scale, which shows the weight of a

Measuring the Amount of Eccentricity

fixed length of tread. From these indications, the operator adjusts the amount of stock fed to the calender. No automatic feed control has as yet been developed, although this continuous scale could be made to change through motors the knives at the mill or the setting of the fourth roll. After being water-cooled, the tread is cut into fixed lengths by an automatic cutter, set to the desired length. The cut treads are check-weighed by the calender crew as the treads are conveyed away from the cutter.

Tubing covers all extrusion processes, from the heavy work of making treads and air-bags to the light work of tubes. In each type, mechanical feeds handle the stock from the mill, while the temperature of the stock is controlled by automatically controlling the temperature of the cooling water. The extruded material is therefore controlled in weight, since the die-head is fixed, and the controlled temperature fixes the rate of flow. A continuously indicating scale, however, is usually installed. Automatic machinery cuts the treads or tubes to length, but man-power is required to book or otherwise dispose of the product.

Curing—After assembling, the tire is placed in the mold for curing, entirely a hand-controlled operation. Curing itself, however, is one of the earliest and best controlled operations. It is the operation on which the entire industry is founded, since it applies Goodyear's discovery that heat converted a mixture of rubber and sulphur into an elastic, waterproof, non-softening material. It is natural therefore that rubber technologists should have developed their knowledge of its practice.

WE FIND automatic means for controlling the temperature, for removing the condensate, for controlling the time for which a given temperature shall be held, following which the temperature rises to be held at a new level, or the temperature and pressure are dropped to ordinary levels. Further developments in the curing of tires must come not in the line of automatic control, but of automatic equipment to cure continuously. A start has been made in this direction, in the design of the watch-case mold. This type adapts itself to conveyor servicing, and to automatic control. The operator removes the tire from the conveyor, places it in the mold, closes it, and the machine does the rest. The automatic valve clamps the mold tightly, then turns on full air pressure inside the air-bag in the tire, follows that with steam in the mold itself, for the predetermined time, at the predetermined pressure, releases it, releases the air, unclamps the mold and opens it. The operator, warned usually by a signal light, is there to remove the cured, and put in another green tire.

In curing tubes, there are two methods in use, the mandrel-cure and the mold cure. In the first, the green tube in a metal mandrel is cured in steam or hot water, the time, temperature and pressure all amenable to automatic control, as with tires.

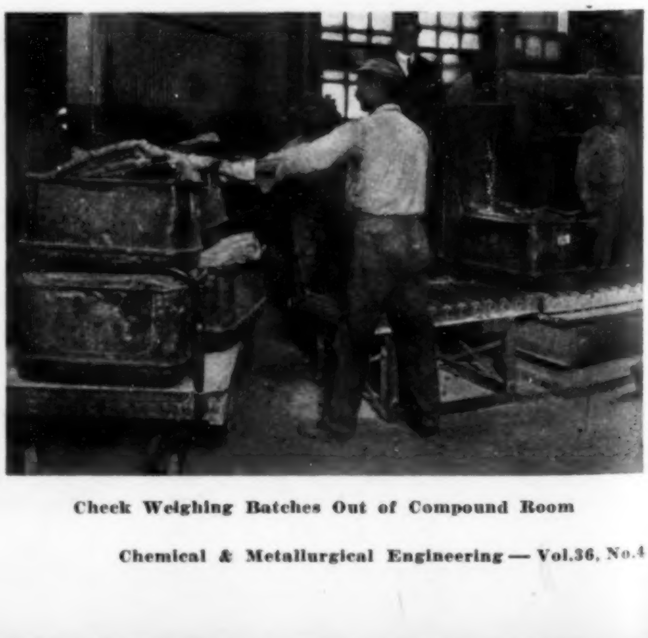
Reclaiming—This branch of the industry is largely a hand-controlled process. Receiving all sorts and conditions of scrap tires, reclaimers must classify them according to age, wear and type (truck, passenger, solids). The beads are cut away, and the tires ground to a uniform particle size. The ground material is then handled through automatic weighing conveyors, to the devulcanizers, where it is mixed with a measured amount of dilute soda-solution. Automatic measuring devices will at this point improve uniformity.

The devulcanizing process, in the almost universally used alkali method of reclaiming, consists of heating the charge under pressure for a fixed time, in the presence of caustic soda solution. The time and temperature may be regulated automatically, exactly as is done in curing tires.

DISCHARGED contents of the devulcanizer are washed to remove alkali. No means are at hand to control the amount of wash water, hence as much as is necessary for peak loads is used all the time. It seems reasonable to suppose that the alkalinity of the washed reclaim could be automatically controlled by varying the supply of wash water.

The washed material, after centrifuging to remove most of the water is dried either in direct flue gas or in an air dryer. In either case means are available for automatically controlling the temperature of the dryer, and hence the final moisture of the reclaim.

Taken as a whole, the rubber industry is sadly lacking in automatic control, control which will cull out the bad, and leave nothing but good product. The processes used do not permit of any great use of automatic control, but the more nearly uniform conditions may be kept, the more nearly do we approach that quality of product demanded by the consumer, that each piece shall duplicate the other.



Check Weighing Batches Out of Compound Room

BEET SUGAR

Industry

Applies Continuous Automatic Control

By George M. Darby
Research Engineer, The Dorr Company
New York

AUTOMATIC control of the highly important first carbonation station in beet sugar factories, once only a dream believed incapable of realization, is now a reality. It has improved carbonation practice to an extent which compares very favorably with improvements made in other branches of the process industries through the adoption of advanced methods of electrical and mechanical control. Five years of development and research work in the field, first on a laboratory scale, then on a semi-commercial scale and finally on a full factory scale, have yielded an improved method of operating the first carbonation station on a continuous automatic basis. This system, known as the Dorr First Carbonation System, has reduced operating labor, increased the capacity of the factory, reduced the sugar loss in the lime mud discard and decreased the unit cost of evaporation through the use of less water for washing on the filters. All of these improvements have been brought about through automatic reaction control based on the fact that the hydroxyl ion concentration in the juice is a function of its electrical conductivity. This chemical-electrical relationship is one that may serve as a basis of control in other chemical fields and the lessons learned from its use in the beet sugar industry should therefore be of value in the broad technique of chemical control.

The beet sugar industry is an old and widespread one, particularly in Europe. About 16 per cent of the sugar consumed in the United States is made from beets. After the sugar has been leached from the sliced beets in the diffusion battery, the resulting sugar-bearing solution is purified by a process which is known as first carbonation. This diffusion juice, dark in color and containing a considerable amount of suspended and dissolved impurities, is heated to about 90 deg. C. and mixed with an amount of calcium oxide, generally in the form of milk of lime, equivalent to two and a half per cent of the weight of the beets. This mixture is then treated with a gas containing approximately 30 per cent CO_2, this gas originating in the lime kiln. The calcium hydroxide and calcium sucrate, which are present at the start, are converted to calcium carbonate which is practically insoluble in the sugar juice. This precipitate carries down with it a large portion of the colloidal and suspended matter so that, when subsequently allowed to settle, the supernatant sugar juice is clear.

Batch Operation With Manual Control.—In the standard batch carbonation system five or more carbonation tanks are usually provided, one of which is always empty and ready to receive juice from the diffusion battery. The tanks are filled in rotation to a given level, the correct amount of milk of lime is added and the gas valve opened wide to permit the CO_2 to bubble through the charge until carbonation is complete. From long experience the skilled operator is supposed to judge accurately the period required for correct gasification. As the reaction nears completion the operator draws off small samples in a glass vessel and observes them in front of a strong light. As the alkalinity is reduced by the gas, the precipitate changes from a gelatinous, non-settling character to one in which signs of flocculation are evident. When flocculation reaches the point which experience has shown to be correct, the operator closes the gas valve and prepares to discharge the finished batch to the filtration station where the juice is separated from the precipitate.

CORRECT carbonation to a juice alkalinity of 0.100 to 0.08 gram CaO per 100 c.c. is essential. If it is not reduced far enough, the precipitate remains flôcculent and cannot be settled, filtered or washed readily thereafter. If, on the other hand, the alkalinity is reduced below permissible limits, a point is reached where some of the impurities previously removed from solution begin to redissolve, thus contaminating the finished juice. A mistake in the judgment of the operator, resulting in a slight variation either way from the desired alkalinity, either causes difficulty in the subsequent separation of juice from the precipitate or impairs the quality of the juice through re-dissolution of impurities.

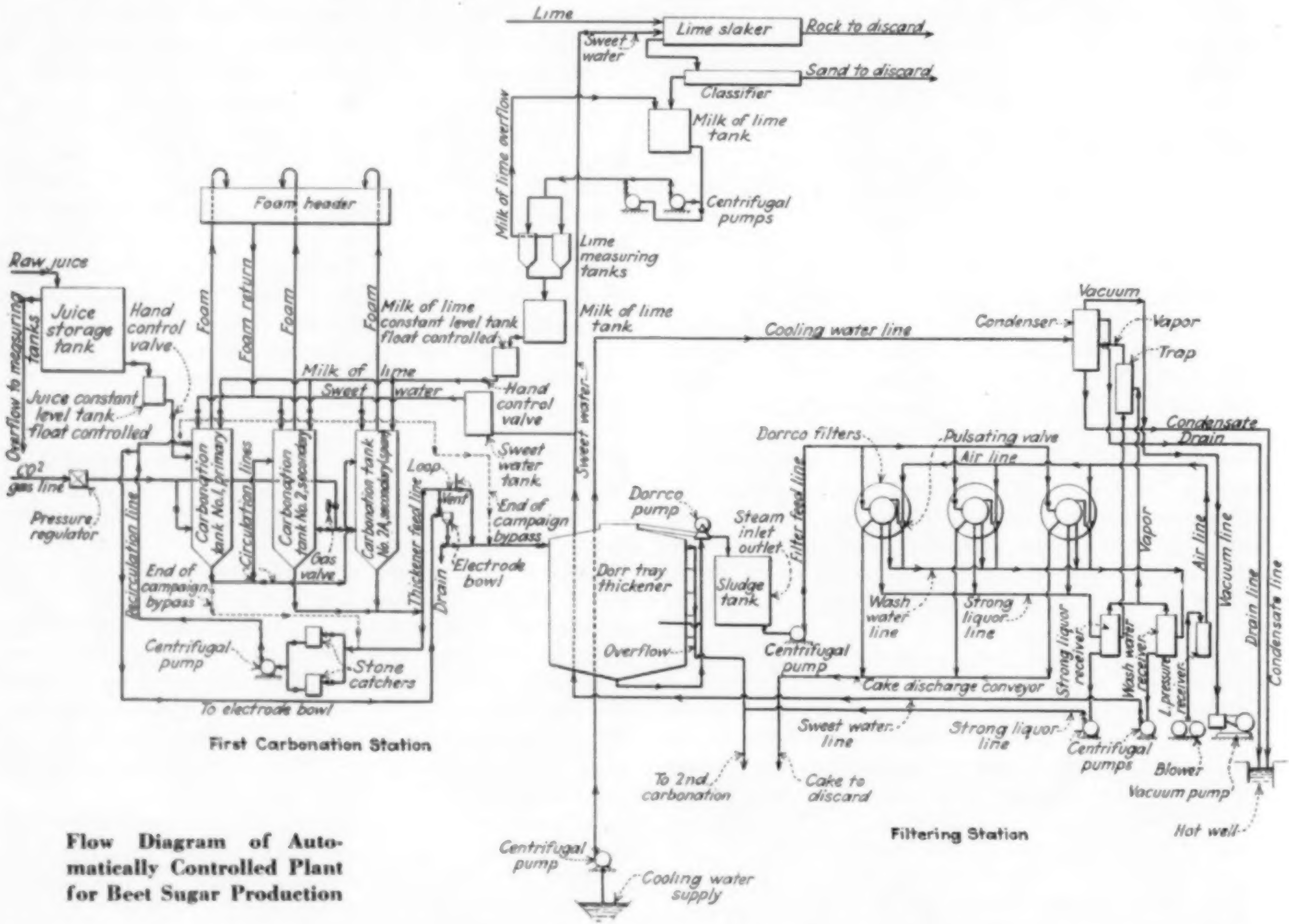
In a normal five tank batch carbonation station, the first tank is generally being filled, the second being carbonated, the third discharging, the fourth full of raw juice and the fifth empty and ready for a new charge. A foreman and a helper operate the five tanks, the foreman watching the progress of the gassing and the helper assisting in the opening and closing of the various valves. It is not in the least unusual for the foreman and his helper to have to manipulate the valves in such an installation 2,300 times during an eight hour shift. With, on an average, a manual valve adjustment every twelve seconds, it is clear that frequently over- and under-carbonated batches escape from even the best operators and seriously affect subsequent treatment.

Continuous Operation with Automatic Control.—The Dorr continuous carbonation system makes the first

carbonation step not only continuous throughout but makes the regulation of the gas valve automatic and not affected to any extent by the diligence or negligence of the operators. Continuity of operation is secured by passing the juice and milk of lime, at a uniform measured rate, through two series-connected carbonation tanks (a third tank is provided as a spare) followed by a special type tray thickener for separating the carbonated juice from the precipitate and a rotary vacuum filter for washing and dewatering it. The automatic, self-regulating feature of the system is based upon the demonstrated fact that electrical conductivity of the finished juice bears a definite known relationship to the alkalinity of the juice. Conductivity recording apparatus was available but it was found necessary to make further refinements and additions in order to secure results of the character required for continuous and automatic carbonation. The finished juice passes through a small receptacle in which four electrodes are immersed. Two of these electrodes are connected to an alkalinity recording instrument which plots a continuous record of the juice alkalinity on a moving chart. The other two electrodes are connected so that at short intervals, if the alkalinity has varied from permissible limits, a circuit is energized to change the setting on the motor-operated gas valve, and thus bring the alkalinity back to the proper value. The lag between corrections is important in order that there may be sufficient time between valve settings for the first correction to take full effect before another connection is made.

As shown in an accompanying figure the raw defecation juice is added to the first carbonation tank at a uniform rate from a constant head tank fitted with a manually regulated valve which once set is not manipulated unless the rate of production is changed. Similarly the grit free milk of lime is added to the carbonators from a constant head tank. The gas entering the carbonation system is maintained at constant pressure by a regulator and is admitted to the carbonators by an electrically operated valve which permits the proper amount to enter to maintain the finished juice at a definite alkalinity. Finished juice flows to a continuous thickener, the overflow from which goes to further treatment while the underflow precipitate is washed, dewatered and discarded. Filtrate joins thickener overflow and is further processed with it. Filter wash, or sweet water as it is called in beet sugar parlance, is used for preparing milk of lime and adjusting the concentration of the defecation juice entering the first carbonator.

The factors governing the formation of chemical precipitates have been the subject of detailed study by the research workers and much research work has been conducted in order to find the extent to which physical conditions affect the properties and structure of the calcium carbonate precipitated in the first carbonization step. The practical application of the findings from these studies has materially improved practice, for by recirculating a portion of the finished juice and otherwise changing process procedure, the precipitate has been greatly modified in form. The more crystalline precipitate produced in this way settles and filters more



Flow Diagram of Automatically Controlled Plant for Beet Sugar Production

rapidly and may more readily be washed free from sugar.

The Automatic Control Instruments.—The automatic control feature of the continuous carbonation system is based upon the relationship which exists between the alkalinity of the juice and its electrical conductivity. While it is true that this relationship is not a straight line function throughout, nevertheless it approaches so closely a straight line function in the particular range of alkalinity which it is desired to hold, that it serves as an excellent means of control. Resistances are determined with alternating current since conductivities measured by direct current are influenced by other effects than simply the resistance of the electrolyte.

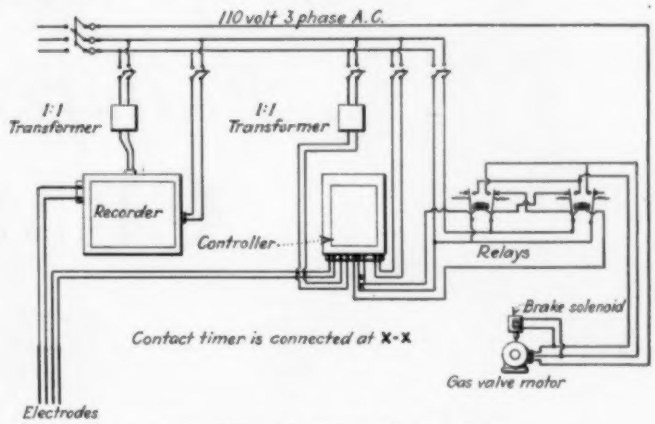
A continuous sample of the carbonated juice is piped from the discharge side of the recirculation pump to the small container known as the electrode bowl in which four platinum electrodes fused in hard rubber or glass tubes are immersed. Two of these electrodes are connected to a recording instrument which charts a continuous record of the resistance of the juice between electrodes.

This instrument has no direct effect on the control of the process, but serves simply to show the operator at any time what the juice alkalinity is and in which direction it is changing.

The other two electrodes are connected to the controller which is quite similar mechanically to the recorder except that it does not have a chart. It operates external relays which in turn operate the gas valve motor to bring the alkalinity and resistance of the juice back to the desired values.

The controller is supplied with three chief adjustments. First, and most important, is the main control dial which may be adjusted to the particular resistance which the controller is to attempt to maintain. If, for example, by titration it is determined that the desired alkalinity, say 0.09 gram CaO per 100 c.c., is equivalent to a resistance of 175 ohms, the main control dial is set at 175 and the controller thereafter will operate the gas valve in an effort to maintain the resistance of the juice at 175 ohms. The second adjustment varies the sensitivity of instrument, causing the element to show a larger or a smaller deflection for a given variation of resistance of the juice from the desired point. The third or so-called "step adjustment," varies the magnitude of any correction which is made by varying the amount of time the gas valve motor will operate at each correction.

The automatic gas valve stem is provided with a worm gear which engages a worm driven by a belt connected motor. The motor is, of course, reversible with its direction of rotation governed by the direction in which the needle of the controller deflects from the desired position. The motor pulley is fitted with a quick operating, electrically controlled brake so that there may be no overrunning of the apparatus after the relay has been cut off.



Connections for Three Phase Motors

This automatic control of carbonation has had a far reaching effect not only on the carbonation step itself but also on the subsequent separation of solution from precipitate, evaporation of the juice and recovery of the sugar. Automatic control has made it possible to carbonate on a continuous basis which in turn has made it possible to circulate a portion of the carbonated juice and secure a modified precipitate of coarser structure which settles more readily, may be filtered more rapidly and from which the sugar solution may be washed with less wash water.

The practical results of the changes in practice directly attributable to automatic control of carbonation are of the following order:

1. Three carbonation tanks (one a spare) required instead of five.
2. One supervising operator at carbonation station instead of two.
3. Continuous clarification by sedimentation and continuous mud washing and dewatering by vacuum filtration substituted for batch filter pressing with large savings in filter cloth, filter labor, upkeep and muriatic acid for cloth washing.
4. Greater production due to formation of more readily handled precipitate.
5. Less sugar loss due to more easily washed precipitate.
6. Less evaporation cost due to less wash water on filter cake.

During the 1928 campaign three factory scale Dorr continuous carbonation system installations were in operation in the United States and one in Europe. Automatic carbonation control may be ranked high among mechanico-electrical control systems based on hydrogen or hydroxyl ion concentration which have so greatly benefitted continuous processing in the process industries. This system is unique in that the improved results are not confined exclusively to the first carbonation step but show up prominently in the subsequent treatment of the juice by sedimentation, filtration and evaporation.

Comparative Operating Figures Before and After Installation of Continuous Automatic Carbonation

	Non Steffens House		Steffens House		
	Batch	Cont.	Batch	Cont.	Remarks
Tons beets sliced per day	1,640	1,800	1,472	1,683	Greater capacity account improved character precipitate.
Tons molasses worked per day	....	....	104	122	
Sugar to 100 CaO in repulped lime cake discharged to waste	2.54	0.94	2.86	1.28	Decreased sugar loss due to a more easily washed precipitate.
Sugar loss lime sewer per cent on beets	0.058	0.021	0.105	0.04	
Per cent wash water on lime cake	178	125	139	105	Less wash water to evaporate and fewer hours of filter operation due to more easily washed precipitate.
Total filter hours	80	48	81	45	
Turbidity of saturated juice	5.9	6	10	3	....

Mechanical Control of Processes Features Modern CEMENT *Manufacture*

By JOHAN NORVIG
Chief Engineer, International Cement Corporation New York

CEMENT industry affords an interesting example of the part played by mechanical control in making possible exact chemical composition and uniform physical performance of a product made under conditions of large scale production. There was produced in the United States during 1928 more than 175,000,000 barrels of portland cement—all made to meet a specification that puts it in the class of a highly technical product.

Everywhere from the quarry to the shipping room mechanical control plays an important part in the manufacture of portland cement. Every step is important and the human element and its uncertainty must be eliminated as far as possible in the production of millions of tons of a product that is remarkable for its uniformity and conformity with definite specifications.

As in all great industries, ingenuity and research have developed many processes for the attainment of identical results—it is not well to claim superiority for any individual system for each is designed to attain results with the raw materials economically available at the place of manufacture.

The variation in the characteristics of raw materials used in the manufacture of portland cement requires a corresponding variation in manipulation, and success or failure is measured by the quality and uniformity of the finished product and the cost of manufacture. Both of these factors must depend on mechanical control, checked continuously by both chemical and physical testing laboratories.

The main constituents of portland cement are lime, silica, iron and alumina, and these elements are procured from varying qualities and quantities of limestone, shale, clay, shells, and other natural deposits.

PROPORTIONING of materials is accomplished in an approximate way when they enter the storage bin. The refinement of this proportioning, as dictated by chemical analyses of standard samples, is attained by mechanical means until the desired combination has been secured.

The storage for crushed rock, shale, or clay may be provided with tunnels underneath so that the material may be withdrawn with a minimum amount of labor. Feeders of different types are used in these tunnels to proportion the various grades of raw material; most common are the rotating table feeders where the stream is controlled by the setting of the scraper blade; the simple gate and chute is also a favorite in this service where great accuracy is not required.

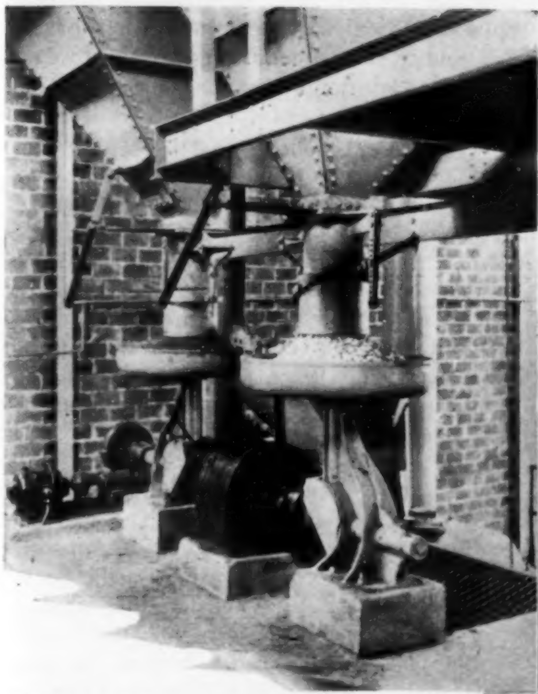
The proportioned raw material is then conveyed to the grinding department by elevators or conveyors and deposited in bins above the grinding machines. Whether one stage or multiple grinding is used is immaterial as far as the next control step is concerned, because in either case it is essential to feed the raw material to the grinders in definite quantities. The fineness to which the material has to be ground is of great importance for quality control and equally so is the quantity output from this department. In other words, the greatest possible output at a given fineness must be produced, and once the speed and design of a mill are settled the only means of controlling these points is by feeding the mill mechanically at a definite rate per minute.

DRY AND WET methods of manufacturing portland cement represent the two major systems. Where the wet process is used, water is added to the raw material as it enters the grinding machine; the general practice is to add just enough water to make a slurry which can be pumped or handled with elevators into and out of the storage basins. The quantity of water is regulated at each mill according to the viscosity of the slurry.

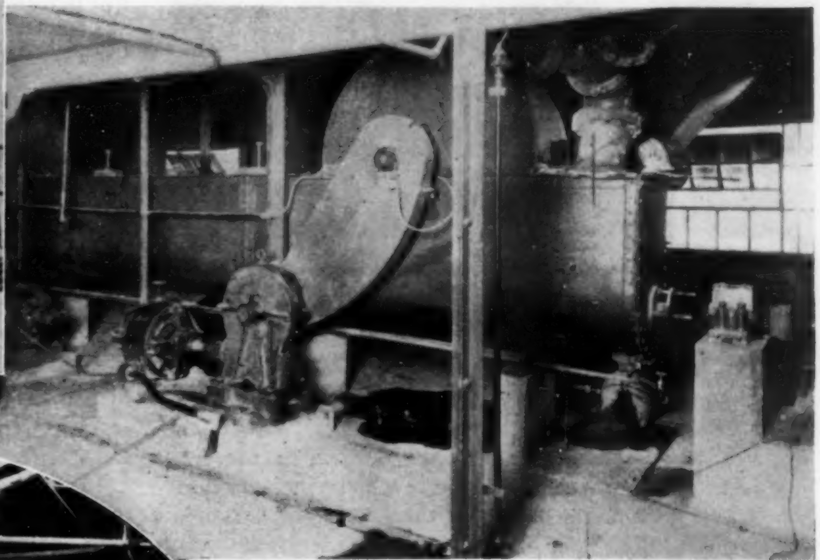
The slurry is stored in large vats (correcting basins) with a capacity of from 10,000 to 20,000 cubic feet and is kept in constant agitation by means of mechanical agitators, compressed air or a combination of both. The contents of these vats is chemically analyzed and the final mix is obtained by pumping slurry from two or more vats into larger basins where the stream is equalized and the whole mass further agitated in the same way as in the correcting basins. Before the slurry is allowed to leave these last basins it is again analyzed and, if necessary, further corrections made, to assure a chemically perfect combination in the form of slurry entering the kilns.

It is important that the quantity of slurry going into the kilns be under accurate mechanical control so as to insure proper burning of raw mix. Gravity type

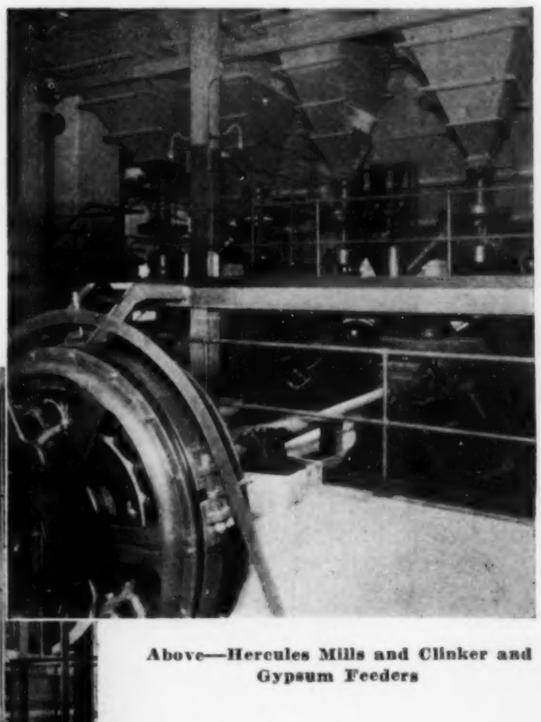
MODERN CONTROL EQUIPMENT IN CEMENT PLANTS

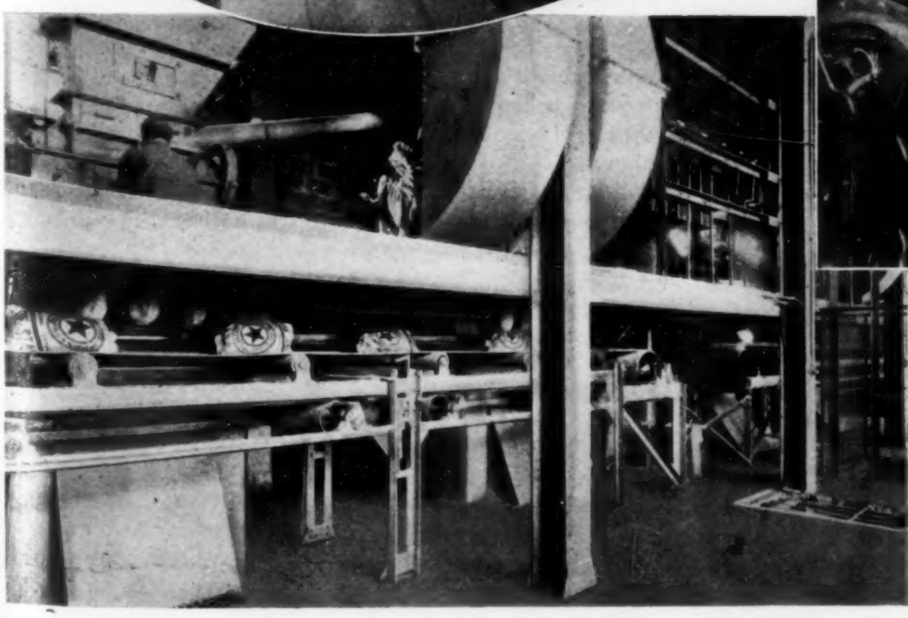


Clinker and Gypsum Synchronized Feeders



Slurry Feeder Trough and Slurry Feeder Drive

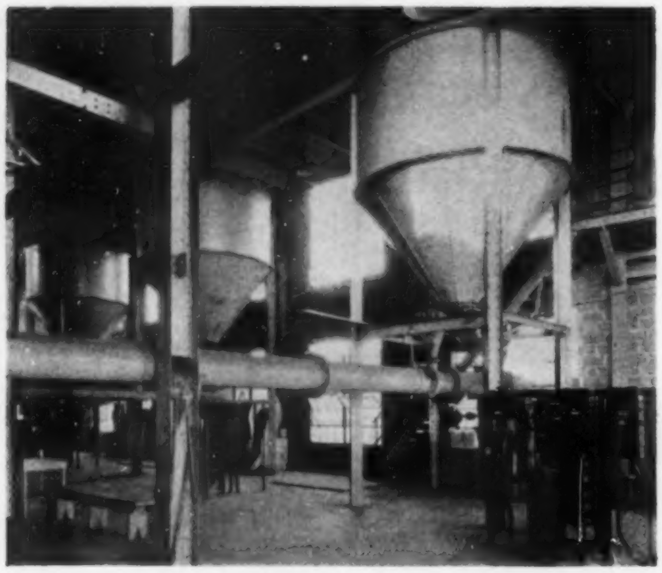




Above—Hercules Mills and Clinker and Gypsum Feeders

In Oval—Raw Tube Mills in Foreground and Slurry Tanks in Background

Left—Where the Cement Is Packed in Cloth and Paper Bags



Three Storage Tanks for Pulverized Coal
Coal feeders are beneath the tanks. The instruments in the lower right corner control the air in the coal blast pipe leading from the kilns.

feeders are used extensively at this stage of the process. These consist of feed boxes equipped with overflow pipes (leading back into the storage basin) so that the level of slurry is constant. In the bottom of the feed box is a valve or orifice through which the slurry is allowed to flow to the kiln. If there is no variation in the viscosity, this is an accurate and simple feeder. By changing the orifice plate the rate of feed can be increased or decreased.

KILNS in a cement plant (at least in this country) are of the rotary type driven either by variable speed motors or by means of some form of mechanical speed controller. This speed control is essential to insure the proper burning and thorough fusion of the raw material as it passes through the kiln; by increasing or decreasing the speed of rotation of the kiln the material can be made to travel faster or slower and thus can be subjected to the heat and the flame for a shorter or longer period.

The firing of the kiln is also under the control of the operator, whether the fuel used is gas, oil or coal. The first two are easily handled by means of valves, and the air needed for atomization and combustion controlled by the same means. A constant check is kept of the temperature of the oil and of the pressure of both the oil and the air.

Coal, as fuel in the kilns, presents a somewhat more complicated problem requiring the pulverizing of the coal so that it may be carried into the kilns on a current of air. For a given quality of coal a certain dryness and fineness is found to give the best results—these two features therefore have to be watched and checked constantly.

It is general practice to have a separate coal drying and pulverizing plant and to store the pulverized coal in tanks in front of the kilns; the coal feeders are attached to these tanks. For many years the standard pulverized coal feeder consisted of a single screw conveyor or sometimes two single screws delivering coal to a blow pipe, the screws being driven by variable speed drives, cone pulleys or variable speed motors. The next development was the multiple screw feeder and lately a rotary type of table feeder has been adopted.

The difficulty has always been to obtain a uniform flow of the pulverized coal with a definite speed of the feed screw; but due to the tendency of the coal to arch in the bin, serious variations have been encountered from time to time. The present forms of feeders are quite free from this fault and the very objectionable so-called "coal floods" can now be entirely eliminated. The quantity of coal for firing the kilns is controlled by the operator as is also the volume of air on which the coal is carried into the kiln; the secondary air (balance needed for combustion) is controlled by regulation of the damper located in the flue between the kiln and the stack, and the kiln operator can regulate with these three variables, not only his flame temperature, but also the length of the flame and the location of the point of highest temperature.

THREE per cent of gypsum must be added to the clinker after it has cooled and before it is ground, in order to control the setting time of the finished cement. This is generally accomplished by some form of synchronized feeders, one of which handles clinker and the other gypsum. Table feeders are used with success in this service—as are cradle feeders for the clinker, timed to operate with a small screw conveyor driven by a variable speed motor for the gypsum. Star or compartment feeders have also been used with satisfaction at least as gypsum feeders.

Besides controlling the ratio between the clinker and the gypsum, these feeders also serve as a control on the feed going to the grinding machines so that these grinders may receive a uniform feed of the correct amount to insure the proper fineness of the finished cement.

As the cement leaves the grinding machines continuous samples are taken from the stream to obtain a final analysis of the product going to the warehouse; a great variety of types of samplers are used ranging in design from the Vezin, removing a definite percentage, to the simplest form consisting of a hole in the bottom of a screw conveyor through which a tiny stream of finished cement trickles continuously into a small sample box.

The last handling of the cement at the mill is in the packing department where the product is loaded into bags on mechanical filling and weighing machines. Both cotton and paper bags are used; they are tied and closed before being filled and the cement is forced in through a simple but absolutely tight valve. The machines automatically shut off the stream of cement going into the bag when a load of 95 lb. registers on the scale beam. The operator simply has to keep the machine supplied with bags and drop the loaded ones onto the conveyor which terminates at the loading platform. In order to check the operation in this department a certain number of filled bags are weighed each day. The result of this checking governs the adjustments of the packing machines.

MECHANICAL control thus plays an important part in every step in the manufacture of cement, insuring absolute uniformity over extended periods of time of an immense tonnage of one of the most important building materials produced. In this way mechanical control provides the insurance of quality of a commodity that is depended upon to protect the lives and the investments of its users—a commodity that has contributed much in the development and progress of the world.

Diversified Controls Serve the

PULP *and* PAPER

Industry

By R. G. Macdonald

*Secretary, Technical Association of the Pulp and Paper Industry
New York*

TEN YEARS ago it would have been much easier to write an article on this subject than it can be done today. Up until that time all of the paper made could be sold and consequently the most valuable man a mill could employ would be the one who could bring out the greatest production. So important was the subject of quantity production that it was felt that the only employees of value in the mill were the equipment operating men. Executives, general mechanics and engineers were considered to be supernumeraries. To obtain ability in obtaining mill production it was felt that long years of operating experience were necessary. Consequently most mill employees began work as boys in the mill and remained as machine operators for a life time.

As in the case of many other process industries the war in 1918 gave the technical man his opportunity. Lack of man power made it necessary to consider how the greatest production may be obtained with a minimum of labor and supervision. This condition led to several important trends in the industry: First, to larger production units including larger and faster paper machines, mills of greater capacity and mergers of paper companies. Second, to a consciousness of the existence of many subdivisions of the industry. Third, the great abundance of available technical school chemical engineering graduates forced the industry to open its doors to such men who were clamoring for admission because of the evidence of opportunities that existed in this field for technical control and improvement. As a result of these trends the industry has become one of tremendous volume and small profit margins per unit and is rapidly coming into line with the major industries in which science plays an important part. Ernest Mahler of the Kimberly-Clark Company has very aptly outlined the functions of a technical superintendent as differentiated from those of an operating superintendent as follows: (1) have charge of process or standard practice; (2) check up on all samples, testing station logs, and reports, daily, and go over the process in detail for variation or tendencies toward variation, reporting to the operating superintendent for corrections; (3) check up tickler against standard practice periodically to eliminate tendencies not apparent daily; (4) maintain a tickler file to remind the superintendent of periodic jobs like cleaning pipes, inspecting rolls, etc.; (5) evaluate new ideas and, if profitable, and approved, work out the solution with the help of other agencies, and with the help of the operating superintendent and staff; after final approval he must incorporate these ideas into standard practice and teach them in class; (6) develop standard practice in meetings with foremen and head operators.

To give a proper picture of the part played by technical control in the pulp and paper industry, it is necessary to consider several district divisions, namely: wood handling and preparation, mechanical pulp, soda pulp, and sulphite pulp manufacture, and finally the conversion of the pulp into the final mill product—paper in any of its many classifications and grades. It is very seldom that we find a mill or even a group of mills of a company making every kind of pulp but for the purpose of this article, we can assume the existence of such a mill.

Wood Handling and Measurements—Inasmuch as wood is the principal raw material of the paper industry we will confine our attention to it. Until recently but a few species of trees were considered suitable to supply pulp wood. These included spruce, fir, and hemlock for the sulphite process, aspen for the soda process and tamarack for the sulphate or kraft process. Today the number of species that are considered to be applicable to treatment in these processes has increased many times. This broader viewpoint has been largely brought about by the work done at the U. S. Forest Products Laboratory at Madison, Wisconsin. In the future we will become intimately acquainted with many new chemical pulping methods and as the availability of certain tree species become less, we will find other species coming into general use in the established and new processes, particularly noteworthy will be the adoption of the sulphite process to the digestion of hard woods.

The variable character of wood makes it one of the most difficult factors to deal with in the preparation of wood pulp. In general it may be said that the wood consumption is calculated from the weight of pulp or paper made. Until recently, there have been no satisfactory means of estimating actual weight of this most important raw material. The unit of wood measurement has been the cord which is quite undesirable because of its variability with reference to the volume and weight of the actual wood substance. In many mills the wood furnished to the grinders is placed in racks holding half cords and the number of racks delivered to the grinder operators is carefully recorded. A cord of wood measures 8 ft. by 4 ft. by 4 ft. and it is evident that the fac-

Control of Pulp and Paper Waste Discharges for Volume, Head and Analyses

tors that affect the volume of solid wood per cord are as follows: straightness of the sticks, extent of occurrence of knots, number of sticks per cord and their diameter.

Some of the mills built during the past few years have adopted a new means of measuring the wood used in the chemical pulping processes. The Anglo-Canadian Pulp and Paper Mill at Limoilou, Quebec, uses a weightometer to continuously weigh the chips passing from the chip-screens to the digester bins. This weighing device which was installed by the Merrick Scale Company of Passaic, N. J., by virtue of an integrating device continually weighs the chips passing over on belt conveyor. Another automatic system of weighing chips is the equipment furnished by the Richardson Scale Company of Clifton, N. J., and is installed in the mill of the Hammermill Paper Company on the Pacific Coast. This type of weightometer has been used in the past for continuously weighing coal and similar materials. Unlike the Merrick scale it does not integrate the weight of material as it passes over a section of a conveyor but uses a tripping device whereby a definite weight of chips is allowed to accumulate, whereupon they are delivered to the conveyor in batches.

Mechanical Pulp—Ground wood pulp made by pressing a log two or four feet long against a revolving stone having a rough patterned circumference is made today more scientifically than it was even a few years ago. The remarkable development of the paper machine has made it necessary to furnish it with pulp fibers that will readily web on the fourdrinier part and which will separate from its water content at a desired rate of speed. There are two principal types of grinders, namely, the hand fed pocket type and the magazine fed automatic type. In either type it is quite desirable to produce a uniform product and this is accomplished by having a uniform pressure exerted by the wood on the grindstone.

In the new Anglo-Canadian mill hydraulic magazine grinders are used and an ingenious electric load regulator controls the hydraulic pressure on the wood so that the power consumption of the grinder motors is kept constant. A ratchet disk penetrating the side of the magazine is rotated by the descending wood and registers the consumption of wood.

There are several control tests used in mechanical pulp mills to check the quality, uniformity and economy of the process. Most mills make routine tests on the freeness, consistency and temperature of the stock coming from each grinder. At present the regulation of these factors is a manual operation. If the consistency is too great or the temperature too high, more water is supplied within the grinder. If the stock is insufficiently free (i.e., is slow in separating from its water content) the stone surface is roughened. A skilled groundwood maker can learn considerable about the way his equipment is operating by studying several individual fibers placed on a blue glass and held up to the light.

In mills using individual grinder drives the horsepower required per cord of wood ground is a valuable figure to indicate the behavior of the corresponding grindstones. In addition to the good pulp obtained there are usually many wood splinters produced which are separated from the good stock by means of screens. These may be formed into coarse sheets on a wet press and after being refined by attrition grinding are suitable for use in wrapper stock. The amount of tailings obtained in this way can be kept very low and should be continually watched. The screens should also be examined at regular intervals to see that they are performing properly.

There is considerable difference in the rate of grindstone wear. On week-ends when the stones are not being used it is the practice in several mills to caliper them to see how much the diameter has decreased in a period of time. This stone wear is expressed in terms of cubic inches per cord of wood ground.

The Sulphite Mill—In the sulphite process there are several well established control tests such as the analysis of the chemicals used including the prepared cooking acid. Inasmuch as the actual cooking is accomplished by sulphurous acid careful watch is kept to see that the acid used has the desired sulphur dioxide content. The Charles Engelhard Company has been developing a sulphur dioxide recorder which will undoubtedly be generally used by the industry in a few years.

The work which was carried on at the Forest Products Laboratory by Miller, Swanson and Mousson has shown that to obtain the optimum yield and quality of sulphite pulp the rate of increasing the temperature of the cooking liquor in the digester is the most important single factor to be considered. In a large commercial digester two hours should be allowed to bring the temperature up to 110 degrees C. If a temperature of 135 degrees C. is reached before the pulp has reached a certain degree of delignification, the cellulose as well as the lignin is attacked, and the yield of pulp is reduced. If the same temperature curve is followed for every cook the pulp will be of uniform quality, other conditions being fairly constant.

The control of the sulphite pulping process is largely manual. Certain standards of procedure have been adopted by individual mills. Each digester is furnished with a recording chart upon which is drawn the temperature pressure line which is to be followed during the cook. The actual temperatures and pressures within the digester are continuously recorded during the cook and the digester operator has to regulate the quantity of steam delivered to the digester and the pressure of the gases within it by opening or closing the steam and sulphur dioxide relief gas valve respectively. In general no endeavor is made to examine the degree of pulping during the process in a manner similar to the examination of the crystal formation in sugar strike pan evaporation. Possibly this will be done as a routine procedure in the future.

Steam flow meters measure the pounds of steam de-

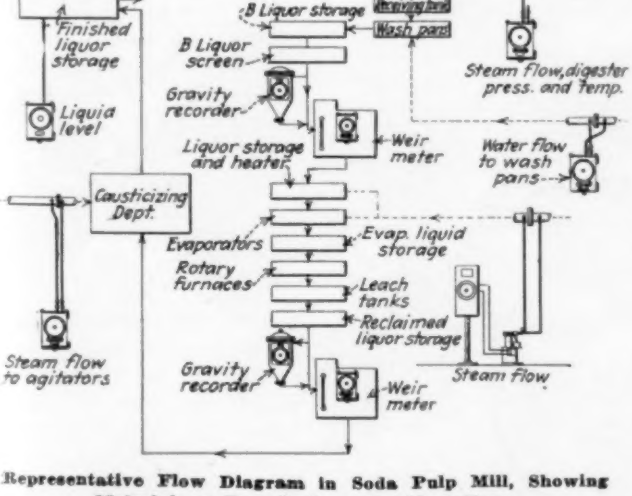
livered to the digester. Knowing the cost of steam per thousand pounds and the value of the pulp product it is a simple matter to estimate the cost of production. The presence of flow meters and indicators in the sulphite mill keeps the operators alert to their duties and if uniformity or quality is not up to standard, a study of the charts will indicate the probable cause.

The Alkaline Pulp Mill—As in the case of the other departments described in this article mention will be made primarily of the trend in technical control, new methods, devices, etc., rather than of the orthodox routine procedure that is followed in each case. In the soda process there is a distinct trend toward the modification of the composition of the cooking liquor used and of the kinds of pulp wood that may be used. In the former case processes such as those known as the Keebra, monosulphate, etc., use liquors other than caustic soda and in the latter case, jack pine, hemlock and other coniferous woods are finding use as well as aspens, birches, etc., which have heretofore been used.

In all of the alkaline pulping processes the criterion of process economy has been the ability of the operators to obtain a high yield of chemicals in the recovery division.

Special attention must be given to the condition of the wood to determine the total pounds of caustic soda to be used in cooking the wood. Since most soda pulp is bleached it is necessary to thoroughly and efficiently wash the pulp to reduce the bleach consumption, to produce a black liquor that is as strong as possible and to reduce fiber losses to a minimum. As in the case of the other kinds of chemical pulp made, the technical department must carefully watch the separate steps of the process.

In the soda pulp industry one of the most interesting recent developments has been the improved method of



Representative Flow Diagram in Soda Pulp Mill, Showing Metering as Described on the Next Page

incinerating the black liquor. Most mills are equipped with rotary incinerators for this purpose but these are wasteful and will probably be replaced by stationary furnaces similar to that designed by C. L. Wagner. To obtain the highest quality of ash from the furnace, careful attention must be paid to have the black liquor delivered to it at the proper density, to regulate the furnace draft, to minimize the stack losses and to watch the condition of the furnace lining. (Alberine stone is almost universally used in the United States for this purpose.)

Screening and Bleaching—When the wood has been converted to pulp, it is necessary to free it from the residual cooking liquor, knots, shives, etc., by washing, screening, etc., and to whiten it by bleaching. Personal inspection is required to see that the screens are performing as they should with respect to speed, condition of the plates, size of perforations and the consistency of the stock entering and leaving them.

In the bleach plant the technical department must control both the manufacture of the bleach liquor and the use of it in oxidizing the impurities in the screened fibers. In preparing the bleach the quality of the lime must be ascertained and the liquor strength must be determined by titration. When the liquor has been chlorinated to the alkaline end-point it is at maximum strength and is sent to the bleaching system. In chlorinating the lime, the temperature must be carefully watched.

In the bleaching operation the man in charge of technical control performs the following tests: (1) Check up of the fiber losses from the brown stock thickeners, (2) Measurement of the density of the stock going to the bleachers, (3) Test of the pulp to determine its bleach requirement, (4) Titration of a sample of the bleach liquor to determine its available chlorine content, (5) Measurement of the temperature of the stock, (6) Determination of the fiber losses when the bleached stock is washed and (7) Qualitative test to detect traces of bleach in the stock.

Stuff Preparation—The screened and bleached pulp may or may not be further processed before being delivered to the paper machine. Sulphite pulp in particular must be evaluated to estimate its paper making properties. With the exception of some of the new newsprint mills it is common practice to treat the pulp in beaters and jordan refiners before delivering the stock to the machine supply system. If the final product is to take writing ink, the fibers must be sized by precipitating rosin on them. The technical department is usually responsible for supplying the directions for furnishing the beaters. In addition to the pulp and water, it may be necessary to add an emulsion of rosin size, alum, clay, color and other materials. To control the beating process tests are made relating to the stock freeness and consistency, temperatured and hydrogen ion concentration.

The Paper Machine Room—The stock delivered by the beaters is screened and diluted from four to one-half of one per cent consistency to prepare it for the paper machine. The stock (now called stuff) is formed into a web or sheet and is carried along by a wire cloth conveyor through which the draining water passes, finally aided by suction. More water is squeezed out when the damp sheet passes from the wire cloth to a felt blanket that carries the sheet through press rolls and finally delivers it to the dryer section which is composed of a number of revolving metal drums into which steam is being constantly passed and from which condensate is removed. Except for the operators skilled in handling the paper machine no attempt is made to control the paper making process by manipulating the sheet. Engineering improvements are constantly being made to make the entire machine perform its desired function as automatically as possible. Electrical control of the machine drive has brought about greater flexibility and numerous systems have been developed to dry the sheet most satisfactorily with the minimum use of steam.

In addition to the effort that has been made to design

paper-drying equipment that would use the least required quantity of steam per unit of paper dried, there have been many inventions that have had for their objective the maintenance of uniformity in the weight and moisture content of the finished sheet. One of the most interesting of these is an invention owned by the Atlantic Precision Company of Boston. This involves the application of a tuned radio circuit wherein a hydroscopic element moves one of the plates of a book condenser in proportion to the extent it is affected by the humidity changes caused by the endeavor of a moist sheet of paper to attain equilibrium with the humidity of the machine at room atmosphere. At least one bond paper and one newsprint mill are having success in using this device in the control of their product.

Meters and Instruments—Before leaving the subject of technical control in the pulp and paper mill, it is worthy of note to observe that the introduction of mechanical measuring and control equipment into the mill has been started and will undoubtedly continue. Meters were introduced into the steam generating plants some time ago and will not be considered here.

A brief outline of the use of meters in a soda pulp mill should be of interest. It is desirable to know the quantity of liquor run into the digester. A liquid level gage installed in the liquor storage tank will give this figure. The steam supplied to the digester is metered and its pressure and temperature recorded. Proceeding through the system a meter for the measurement of wash water is found, which should be recording and integrating so that the total flow of water consumed and the time involved in washing known, as an excess of water means increased steam consumption by the evaporators and a deficiency of water may mean that all of the caustic has not been removed from the pulp. The combined waste liquor and wash water are then passed through a gravity recorder and the quantity of black liquor is obtained, enabling the evaporator operators to regulate the steam to the evaporators so as to maintain the gravity of the liquor delivered to the rotary furnaces at the standard desired.

Following this the measurement of steam to the evaporators is highly desirable for the purpose of calculating costs and the use of pressure and temperature recorders on each effect of the evaporators is necessary for determining their efficiency. The recovery furnaces should be equipped with CO_2 and temperature recorders for the flue gases leaving the furnace and a draft having the proper range should also be used.

The next point of application is that of a gravity recorder and weir meter on the green liquor line to the causticizing department. Such an installation gives the operators in the causticizing department the information needed for the proper addition of soda to obtain the desired quality of finished cooking liquor. Other meters for the soda pulp mill include a steam flow meter for the measurement of steam to the agitators in the causticizing department and temperature recorders for each agitator in order to control the boiling period.

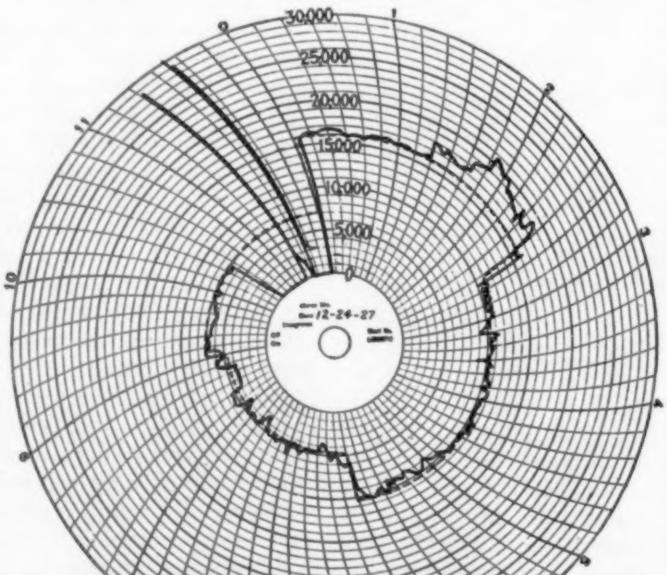
Sulphite Process—The digester metering equipment should be the same as for the soda mill. Sulphur dioxide recorders are obtainable for the sulphur burners and gas meters for the measurement of gas flow to the absorption towers, as well as the relief gas from the digestors. The flow of water to the coolers and the temperature of the exit gas should be recorded, as the rate of cooling of the gas has a decided effect on the formation of sulphuric acid in the cooler, it being desirable to reduce the temperature of the gas as fast as possible through the range of temperature where acid forms. By recording the flow and temperature of gas and water to the absorption towers, it is possible to regulate the strength of acid produced, although the temperature in the tower has a greater effect on the quality in that it is the governing factor of the amount of available acid in the liquor, so that a very desirable feature is the control of temperature of water and gas in order to produce the desired strength of acid from day to day.

In the mechanical pulp mill it is desirable to record the individual grinding temperatures inasmuch as excessively high temperatures have a detrimental effect on both the stock and the grindstone.

Bleach Plant—Steam flow meters, specific gravity recorders and liquid flow meters find use here. In the paper mill there is a need for steam flow meters to measure the steam used for drying and for recording tachometers to measure and keep record of the speed at which the equipment is running.

The measurement of white water has become extremely important in recent years in connection with various systems intended to eliminate fiber and chemical losses. Most plants interested in this problem have installed weirs and liquid level recorders to give a check on the flow of water from the paper machines, deckers, etc.

The foregoing survey of the methods used to make a high quality and uniform product in the pulp and paper industry cover the more important and general phases of the subject. It should, however, be kept in mind that technical control is new to most mills and consequently local conditions dictate the extent and manner in which control methods are applied. The disturbed economic situation of the industry will force many mills to investigate their processes to determine how costs may be reduced to a minimum without decreasing the quality of the product made.



Typical Steam Consumption of Sulphite Digester
Dotted line is drawn on chart by operator from a template; the full line, giving steam flow record, corresponds nicely with this desired operating line.

Automatic Pressure Regulation Aids in NATURAL GASOLINE Recovery

By J. V. Thomas

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Typical of the attitude of the petroleum industry toward automatic process control is the wide use to which pressure regulation is applied in the recovery of natural gasoline. Through the constructive criticism and suggestions of the personnel of the industry, the manufacturers of automatic controllers have been able to develop many types of equipment that meet the present day demand for accurate and continuous control.

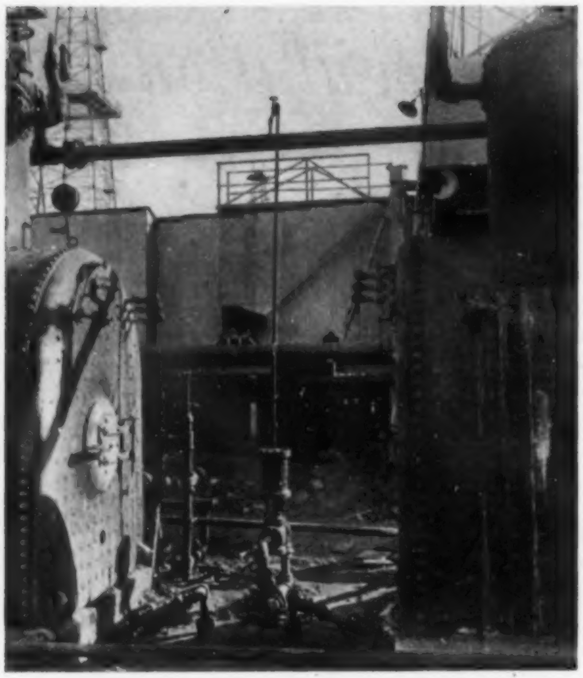
The entire field of pressure regulation as applied in the petroleum industry may be segregated into six types, namely: (1) reducing regulators, (2) back-pressure regulators, (3) gas-fuel regulators, (4) pump governors, (5) vacuum regulators, and (6) differential or volume control regulators. The primary duty of any regulator is to maintain automatically a given pressure within very close limits. The differential regulator maintains a given difference in pressure. Inasmuch as gas-fuel regulators and pump governors operate and are constructed exactly like reducing regulators, it is only their application that is classified above. Of course it is the limits within which it is desired to maintain this given pressure that determine whether or not the regulator should be pilot operated, and this matter rests entirely with the user. In the present paper the design, operation and general application of each of these types will be briefly discussed.

Reducing Regulators. The duty of the reducing regulator is to take fluid delivered to it at any pressure, reduce that pressure to the pressure desired and automatically maintain that pressure within very close limits. Reducing regulators are always governed by the outlet pressure, the diaphragm being connected to the outlet side. They are so constructed that as the pressure increases on the diaphragm, the valve mechanism closes and as the pressure decreases, the valve opens.

One of the common uses for pressure reducing regulators is for supplying a constant low pressure for gas-engine fuel. Until very recently it has been the practice to install two reducing regulators for furnishing fuel to gas-engine driven compressors. One regulator would reduce the pressure from 30 lb. or whatever it may have been, to about 5 lb. The second regulator would then take this 5-lb. gas and further reduce it to the desired lower pressure, which sometimes was as low as one or two inches of water pressure.

It is now considered good practice to make this pressure reduction in one stage. Not only is one regulator eliminated, but a much smaller regulator may be used. For example, where a 2-in. high pressure regulator and a 3-in. low-pressure regulator would have been required by the two-stage method, a single 1-in. reducing regulator is sufficiently large to handle the job alone, and at about one-fourth the cost. The latest type regulators are just as capable of reducing 30 lb. to one ounce as 5 lb. to one ounce, and are equally reliable. Of course, the same size header is necessary and the small regulator should exhaust directly into the header. The actuating pressure for the diaphragm should be taken off the middle of the header. This extremely low pressure permits the use of very large diaphragms with which remarkably accurate results may be obtained. For this reason it is

The Installation Below Shows Both the Single Diaphragm Type of Regulator and the Pilot Operated Type. Both Are Field Boiler Plant with Gas-Fuel Regulator



Field Boiler Plant with Gas-Fuel Regulator

unnecessary to use a pilot-operated regulator for gas-engine fuel.

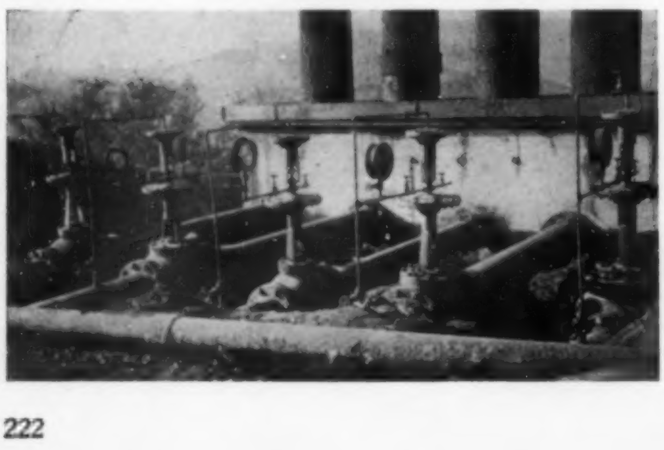
A reducing regulator set to maintain the desired pressure can be installed at the inlet of any system in which a fluid pressure is carried with the assurance of protection against excessive pressure on the equipment. This applies to instances where the incoming fluid is subject to fluctuation caused from an external and uncontrollable source.

Reducing regulators are used extensively by gas companies for feeding their low pressure distributing systems. Similar uses are made of reducing regulators by the oil companies where it is desirable to prevent excessive fuel line pressures.

Back-Pressure Regulators. The action of regulators of the back-pressure class is the reverse from the action of reducing regulators and the application is exactly opposite. Instead of maintaining a constant outlet pressure, back-pressure regulators maintain a constant inlet pressure. Such regulators are also known as relief valves, check pressure valves and even the pop valve belongs to this class.

There are many uses for back-pressure regulators in natural gasoline absorption plants. The most general applications are: (1). The blow-off regulator, for preventing plant pressure building up when no other disposition can be made of treated gas. (2). A regulator on each other line through which treated gas is transported, such as to lease fuel systems and sales lines. This prevents the plant suffering from the fluctuations in pressure caused by increasing and decreasing demand for gas. (3). Back-pressure regulators installed on gasoline storage tanks and high-pressure and low-pressure accumulators prevent the rapid vaporization of lighter hydrocarbons caused by any sudden release in pressure. (4). Any other equipment throughout a plant which operates at greater than plant pressure should be controlled at the outlet by a back-pressure regulator.

Battery of Pilot Operated Back-Pressure Regulators in a Gasoline Plant



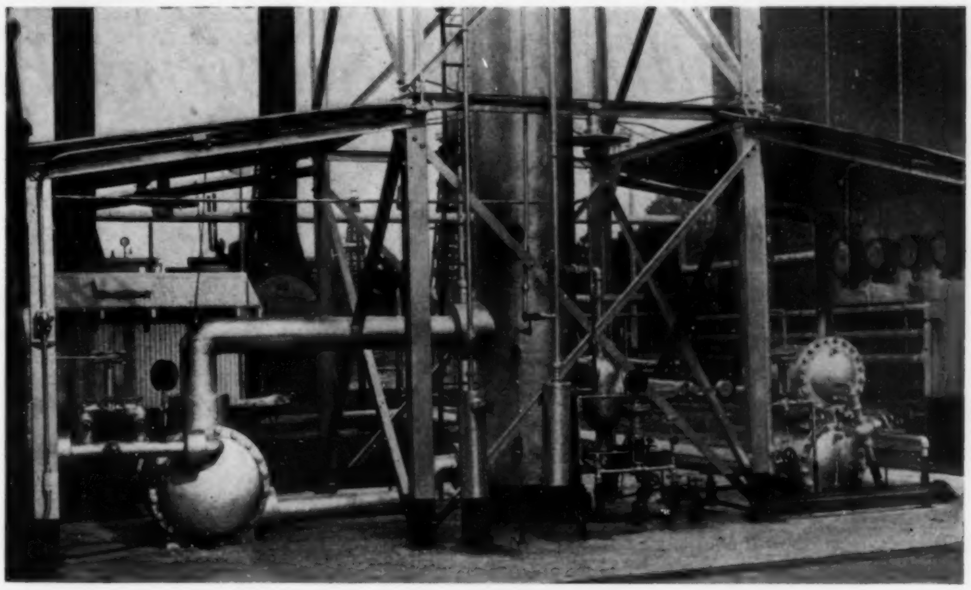
This type of regulator is also used in the oil fields to maintain constant casinghead presures or back pressures on gas and oil separators. Wherever a well is producing into a system in which the pressure fluctuates, these fluctuations affect the well pressure accordingly. Usually this condition is extremely detrimental to the well and may be eliminated by back-pressure regulation.

The operation of back-pressure regulators as compared with reducing regulators may be clearly defined as follows: Back-pressure regulators relieve fluid from any system in the same quantities and at the same rate as such surplus fluid is being introduced; reducing regulators introduce fluid into any system in the same quantity and at the same rate as such fluid is being consumed or disposed of.

Typical Field Installation of a Gas-Fuel Regulator and a Reducing Regulator Showing Bypass and Connection to Steam Header

Gas-Fuel Regulators. Gas-fuel regulators are sometimes called boiler governors or gas-steam regulators. Their purpose is to feed gas automatically to burners under steam pressure under varying conditions of load. Their action is similar to that of reducing regulators in that increased pressure on the diaphragm closes the valve mechanism.

Gas-fuel regulators are installed on the gas header to the burners and steam pressure is connected to the diaphragm. The steam connection may be taken from the main steam header near the boiler or boilers, but preferably from the top of each boiler or steam drum, where the pressure is stationary. Constant steam pressure is recognized as being of vital importance to gasoline plant operation not only from the standpoint of efficiency but by eliminating frequent hand adjustments by plant operators.



These Pressure Regulators, Liquid-Level Controllers and Temperature Controllers Are Used in Automatically Controlling a Stabilizer Column in a Natural Gasoline Plant

Pump Governors. As the name implies, regulators of this type are largely used to control the operation of steam-driven pumps. The valve is installed on the steam supply to the pumps and the diaphragm connected to the pump discharge. As the discharge pressure of the pump slightly increases or decreases, the diaphragm mechanism closes or opens the valve, thus decreasing or increasing the speed of the pump to maintain the desired pressure.

Pump governors, boiler fuel regulators and reducing regulators are all similar in design and operation. Wherever it is desired to maintain a constant pump discharge pressure, a pump governor is required. A common application of this type of equipment is in controlling the output of compressors. A regulator of the reducing type can be installed on the suction to the primary stage with its diaphragm connected to the discharge pressure on the high side. The desired discharge pressure can then be maintained with the entire elimination of hand control, regardless of the size or number of compressors in the plant. In some cases, perfectly satisfactory results may be obtained by installing a small regulator on a bypass in order to throttle a greater portion of the intake through a hand valve on the main line.

Vacuum Regulators. The chief difference between vacuum and positive pressure regulators is in the diaphragm construction. The spring, or weight, must be so located that it opposes the force exerted by the difference between the atmospheric pressure and vacuum. Briefly, vacuum regulators are made to function in two ways which correspond to the function of the regular reducing and back pressure instruments—first, to close when the vacuum increases or in other words, when the absolute pressure decreases and second, to open when the vacuum increases. The first type would be installed on the outlet line from a system with the diaphragm connected upstream. The second type would be installed on the inlet line to a system with the diaphragm connected downstream.

As in the case of low-pressure reducing regulators such as are used to control gas-engine fuel, the low working pressures encountered in vacuum regulation permit the use of extremely large diaphragms, thus eliminating the necessity of pilot-operated equipment.

Differential Regulators. All diaphragm operated regulators, whether equipped with weighted lever or spring, are in reality differential regulators because in any case there are two pressures at work, one of which is generally atmospheric pressure. This latter pressure being comparatively constant, is sometimes forgotten as playing any part in the operation of regulators. Where pressures above atmospheric are regulated, the constant atmospheric pressure works to assist the spring tension. In the case of vacuum regulators, the atmospheric pressure opposes the spring tension, or weight.

The term differential regulators, however, is particularly applicable to a certain class in which both sides of the diaphragm are direct-connected to the fluid being controlled. This type of equipment has many special uses, but mainly is used to control or maintain a desired rate of flow. This is accomplished by maintaining a predetermined difference in pressure between the upstream and downstream sides of an orifice installed in the line through which the fluid is passing. The differential regulator is installed on the same line, either above or below the orifice. The high-pressure side of the diaphragm, that is the side of the diaphragm opposing the spring tension or weight, is connected to the upstream side of the orifice, the low-pressure side of the diaphragm being connected to the downstream side of the orifice. The spring tension or weight is set for the desired difference in pressure. Changes in flow may be made either by changing the size of the orifice or altering the adjustment of the regulator.

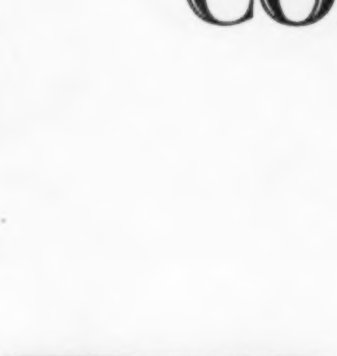
Liquid-Level Control. The standard type of liquid-level controllers are in general use in gasoline plants and refineries where a constant level of oil, water, gasoline or combinations of these fluids is required to be maintained. These controllers may either control the flow directly by operating the valve on the inlet or outlet line or indirectly by throttling a pump.

A few specific applications of liquid-level controllers in natural gasoline plants are: to maintain a constant liquid level in tanks, to maintain a constant oil level in absorption towers, to hold a constant water level in the separation of water and gasoline in absorption plant receivers.

Regulator Used in Reducing Gas From 250 lb. to 5 lb. for Gas Company Distributing System

Controlling and Servicing Instruments in a COAL PRODUCTS *Plant*

By H. J. Meredith
Chief Chemist, Seaboard By-Product Coke Company Kearny, N. J.



All industrial plants, particularly those of a chemical nature, are subjected in some measure to the necessity of maintaining instruments ranging in complexity from simple indicating gages and thermometers, to recording CO_2 meters and calorimeters. The number and variety of these will determine the advisability of employing a man to inspect and repair them as well as the type of man to be employed. One, or several complicated instruments of the same kind can be handled in part time by a mechanic, properly attuned to the vagaries of delicate apparatus. Usually a philosophical one can be found whose ego can be inflated sufficiently to make him assume the responsibility without demanding the pay of a specialist. The policies of the Department of Immigration have a far reaching effect on the number of such men in an organization.

Most instrument manufacturers are willing to service their equipment, so that it is only necessary to 'phone the local agent and call for help when the occasion arises. Very often, however, the bill at the end of the month reveals an expense item that seems to be at variance with the caliber of the service "engineer," and when a plant has a variety of instruments, this could amount to a considerable expense and cause a lot of delay, especially in plants not favorably located near a large city.

The idea of a central control for instruments needs no defense and its necessity grows with their number. At Seaboard, the instrument department, like "Topsy," just grew and as certain indicators and recorders, weightometers, etc., gave trouble they were turned over for maintenance to it. Sometimes it is advisable to have apparatus that is used in measuring outgoing materials, calibrated and checked independently by the manufacturer, thereby manifesting evidence of good faith with customers.

It is proposed to give a list of instruments used in this plant and those to whom such things are uninteresting are warned to overlook the subjoined.

(1) 4 — CO_2 recorders
(2) 4 — Weightometer scales for coal and coke
(3) 2 — Recording calorimeters
(4) 1 — Electrical resistance gas meter
(5) 9 — Recording pyrometers
(6) 3 — Recording shunt ammeters
(7) 20 — Recording pressure gages
(8) 3 — Flow meters
(9) 4 — Integrating, indicating and recording gas meters
(10) 2 — Integrating, indicating and recording liquid meters
(11) 23 — Indicating flow meters for gases and liquids
(12) 2 — Liquid level recording gages
(13) 5 — Temperature control instruments
(14) 22 — Recording pressure, draft and pressure draft-instruments
(15) A lot of steam gages, which give so little trouble that their numerical identity is not known
(16) Considerably more indicating thermometers than pressure gages and which have almost as clean an operating record
(17) A medley of U gages dignified into "indicating manometers."

These are distributed without respect to types throughout the plant about as follows:

Byproduct Department

1 — Recording calorimeter
1 — Electrical resistance gas meter
3 — 2-pen pressure gages
1 — Oil meter
11 — Indicating flow meters
3 — Temperature control instruments
6 — Recording pressure, draft, and pressure-draft instruments
13 — Recording pressure gages
18 — Recording thermometers
And of course steam pressure gages and indicating thermometers

Producer Plant

1 — Recording calorimeter
3 — Flow meters, indicating, integrating and recording
6 — Recording pyrometers
1 — Recording pressure, draft and pressure-draft instruments

1 — Weightometer scale
6 — Indicating flow meters
8 — Recording thermometers
2 — Recording pressure gages
3 — Indicating manometers
1 — Water meter

Boiler House

4 — CO_2 recorders
1 — Water meter
1 — Recording pressure gage
2 — Recording, integrating, and indicating liquid meters

Batteries

16 — Pressure, draft and pressure-draft instruments
2 — Integrating, indicating and recording gas meters
2 — Recording pyrometers
3 — Recording shunt ammeters
1 — Bulldog water meter
2 — Water level gages
1 — Recording thermometer

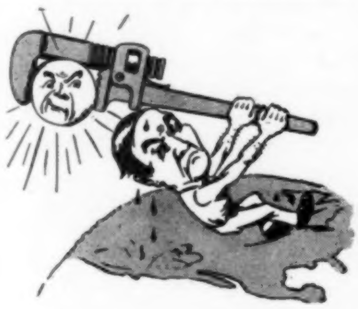
Coal Handling Department

1 — Weightometer scale

Coke Handling Department

2 — Weightometer scales

It would be obviously out of the question for the foreman of the byproduct plant, the producer plant, the boiler house or the batteries to look after his own instruments, for unlike the solar system or the tides, these do need occasional attention and sometimes one is inclined to think that they are equally difficult to adjust. Even the manufacturers have been known to resort to the great American pastime of passing the buck when a controversy arises, so there is no need to expatiate on the disadvantages of departmental control of instruments.



There are several advantages in having the laboratory supervise the instrument department, especially when one considers the work involved in checking calorimeters, gas meters and CO_2 recorders. The temperamental compatability of the men required for both kinds of work is by no means last on the list. There are various ways of giving vent to one's feelings in time of trouble and the type of man that uses a wrench on a needle valve (and they are legion) is the one that justifies padlocks and fool-proof cabinets.

It has been found advisable that the man in charge of the instruments should understand the theory of the instruments he repairs as well as the processes which they control. To him an algebraic equation and possibly an integral sign should not be too debilitating. A college degree does not automatically qualify one for this job. Although there is no necessity for him to know a lot of mathematics, he should at least have forgotten some and have taken possibly the equivalent of a recognized engineering course, so that he is able to use some discrimination, backed by knowledge, when trouble arises. He must have an intelligent perspective of the significance of the instruments under his control to the plant.

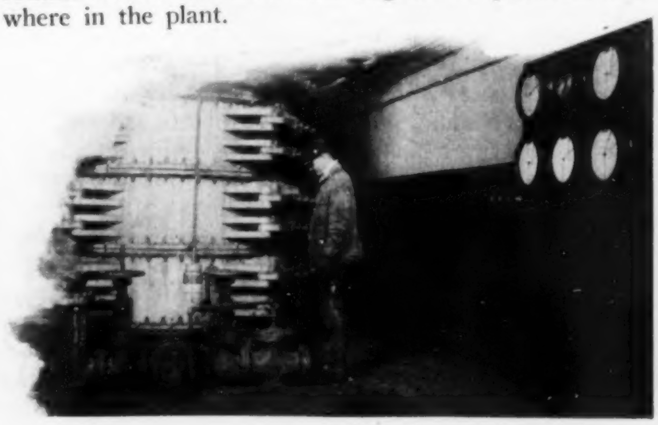
Under him is a chart man who collects all the charts and winds the clocks in the recording instruments every day, and reports any mechanical difficulties or infractions of the rule that he alone is to adjust the apparatus.

This does not altogether curb the activities of some men whose curiosity to see the wheels go round has survived the cradle. It is sometimes necessary to lock the instrument case, but in general very little difficulty in this respect is met. He is confronted, from day to day, with a lot of trifling difficulties which demand attention, and if the various departments maintained and repaired their own instruments, they would eventually arrive at Chesterton's conclusion that "Reason will tell anyone but a fool to attend to little things. The bullet that kills a man is a little thing, the pill that saves his life is a little thing. It is by his consciousness of little things that a man proves himself to be alive." This man's daily routine justifies his interest in meteorological reports, but it does not permit him to store up rainy day jobs. His morning is spent on the beat in the plant, and the afternoon finds him sorting, averaging and integrating his charts before submitting them to the superintendent, who passes them along to all the foremen and engineers interested. They are finally returned to the laboratory and filed away on pegs or in drawers seemingly for posterity, but at the end of the year they are all discarded except those for the 7th and the 15th of the month.

The millenium according to the lights of the chart man would doubtless include mercury gages that won't blow, clocks that keep time, inks that don't thicken, fountain pens that don't plug and especially operators that don't meddle. Utopia would realize all these and centralize all the charts on one board as well.

The man in charge of the instrument department takes a finger print of all the apparatus under his supervision and keeps a complete card index of all the equipment, in operation or in stock, from the humblest flow meter up. This experience leaves him with a very decided bias as to the relative merits of the available meters on the market and fortifies him against that old bogey "High Pressure Salesmanship."

It has been found desirable to associate other duties with the instrument department, which consists of four men, at this plant. It oversees all sampling of coal and coke and the metering of gas, which duties may not seem closely allied to the main one, but experience has shown that this rounds out the responsibilities of the department sufficiently well to justify its separate identity and makes work in both more interesting for the men, as it offers a greater opportunity to relieve the monotony of routine work and makes them eligible for positions elsewhere in the plant.



Some Operating Views of

INSTRUMENT CONTROL

By Fred M. Reiter
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PLANT operators of today certainly have it over their predecessors in ease of operation and control of processes. In plants of past days, without instruments or automatic control, men had to "feel" the operation of their equipment. The various "diseases" of the apparatus gave peculiar symptoms that warned the experienced attendant of impending trouble. In years of contact he had acquired a sixth sense that made him a highly skilled artisan, with a knowledge he coveted and hesitated to pass on to others. There were no short-cuts to such learning.

Present-day control would be a revelation to him. The many "eyes" that we possess, in our instruments, penetrate the shells of our stills, extractors and condensers, and peek into the seething materials contained there to tell us, almost in words, just what is going on. Practically every part of our industries is controlled: processes, handling of materials, time purchasing, selling, and even the human factors.

IF THE PLANT is large enough, one man, with assistants if necessary, should devote all his energies to the maintenance and upkeep of control equipment. In smaller plants, with few instruments and controls, a definite portion of one man's time should be assigned to this task, with full responsibility for their continuous functioning. Under no circumstances should others be permitted to tamper with such important and probably fragile devices.

Every part of the control equipment should have a scheduled routine of inspection, even though its operation is perfect. This would provide different intervals between inspections for different classes of control. For some installations, such as those governing dirty and viscous liquids, or operating at high temperatures or pressures, inspections should be more often than for those functioning under more ideal conditions. It is too late to inspect a piece of equipment after it has broken down.

AN INTELLIGENT operator will understand how much easier it is for himself to have his work controlled without his constant efforts. He will realize that automatic control with plenty of instruments is a useful assistant. To some, particularly new men, control systems are intricate and intangible, something to worry about. One failure may ruin the confidence of such a man.

In most cases, probably, he is unfamiliar with the principles and operation of the controller. Some managements prefer to keep the men ignorant in this respect so that they will not tamper with the instruments. In my own experience, this attitude has caused more harm than good. The operator should always send for the proper man in case of failure or break-down, but an acquaintance with the equipment will enable the plant to run more smoothly and avoid serious failures.

Fundamental to the successful utilization of control systems is their complete exploitation. I have witnessed a number of plants that were designed by consulting engineers and completely equipped with automatic control systems which were ultimately permitted to degenerate to hand operation.

Particularly do I recall one plant where a battery of stills was heated by exhaust steam from a large installation of reciprocating engines. The surplus exhaust steam was returned to the boiler house feed-water heaters through automatic relief valves. Automatic pressure control valves admitted live steam at 175 lb. to maintain the required exhaust steam pressure of 15 lb. Before long the still operators found it convenient to open by-pass valves on the high pressure control valves so that they had plenty of live steam for their own use. Adjustments of the proper valves would have resulted in perfect control with worth-while economies.

The same condition developed on a series of twelve coolers, where hand operation of by-pass valves (necessary for emergencies) gradually replaced automatic control. This set of controls did not receive proper attention due to lack of understanding of the mechanism. Later, the apparatus was repaired and all hand operation eliminated, with remarkably improved results.

Records made by the instruments are the evidence of the proper functioning of the plant. I have met some operators who consider recording instruments as tale bearers, preferring indicating instruments that tell no tales. Such shortsightedness is fortunately rare, as the improved production speaks for itself. To me, charts have always been forecasters of possible trouble, for when the line just commences to deviate it is a warning to be on the look-out; a very slight adjustment of valves straightens it out again. After the line is badly bent, it takes considerable effort to bring it back. The best way to keep it straight, is to see it often. Convenient location makes this easy.

SOME further points that I have found of value in this general connection might be mentioned:

1. Standardize in make, size, range, charts, elements, mounting, etc. This assists the storekeeper, purchasing agent, and the repairman.

2. The purchase of instruments should be in the hands of one who thoroughly understands the application and object in view, as well as the characteristics of the various types of instruments.

3. Mark and file charts carefully and make a conscientious interpretation of the records.

4. Instruments should be kept polished and clean. Periodic attention and checking is necessary and failures in inking, winding, supplying charts, must be avoided.

5. Instruments should be most conveniently mounted. Centralized gage-boards are preferable. A two-pen instrument is better for related records than two single-pen, both for economy and interpretation.

6. Instruments should be calibrated for corrections due to water legs, long lead-lines, etc. The readings on the instrument should tally with those at the point of connection—the equipment—and not with a test instrument in the laboratory. Instruments should have double connections at the board for convenient checking. Thermometers

should have duplicate wells in the lines for check thermometers for simultaneous testing.

7. The instrument should be protected against outside conditions: vibration, freezing, excessive temperature, collision with moving bodies, and the like.

Recording instruments are of no less value to the management than the operator, in checking the days' operations to insure best results. Appropriations are rather easily obtained nowadays for such equipment through the expectation of increased profits from the investment. Failure to derive these benefits is an almost certain indication that some of the conditions suggested above should be investigated.

Heavy WEIGHING *Can be Accurate*

Track Scales are a Necessary Control Tool for the Large Producer

By Fred D. Hartford

Engineer, Burkhardt Steel and Iron Works Denver, Colo.

MOST CHEMICAL PLANTS receive raw materials of various kinds in car-load lots and after processing them ship out the finished products in the same manner. Chemical operators are accustomed to stress unit prices, chemical composition, and freight rates. On the other hand, comparatively little attention is paid to the accuracy of the fundamental factor of weight. Most plants depend on the railroad company for the correct weight of the cars. Only the larger works are provided with railroad track scales of their own to secure a check on the railroad's weight figure.

Although scales of the railroad companies are generally kept in better adjustment and repair than those of industries, yet there are many railroads notorious for bad weighing practice.

In 1919 the Bureau of Standards of the Department of Commerce was instrumental in bringing together the various national interests concerned with the problem of car weighing—the Interstate Commerce Commission, the railroads, the scale manufacturers, and certain state commissions—to formulate a specification for the manufacture and installation of track scales. A result of this collaboration was the publication of the famous *Circular 83* of the Bureau of Standards. No less valuable to industry were the accurate test cars built and operated by the Bureau. The practical result of this organized interest has been a monumental improvement in all phases of railroad weighing.

DESPITE this betterment of weighing practice, it is doubtful if actual average railroad weighing today is closer to correct values than 8 lb. per ton. The writer has examined not a few cases where the error was from 10 to 20 lb. New track scales, after final test and adjustment should show an accuracy of 1/20 of one per cent, or one lb. per ton. When scales in use reach an error of 4 pounds per ton, they are supposed to be taken out of service and repaired.

The chemical business of the United States probably exceeds 40,000,000 tons of freight per annum, not including coal, ore, and metals, so that an error of 8 lb, per ton means that 160,000 tons of chemicals are yearly given away or paid for twice. Since poor scales usually weigh "light," it is certain that they can inflict chemical producers with heavy loss.

CHEMICAL engineers who have struggled to raise yields to the highest possible point and to cut costs to the bone are in no humor to see the results of their toil given away by a bad set of track scales. Doubtless many chemical plants which now depend solely on railroad figures would find it to their advantage to provide track scales of their own. However, the installation would be of no value to them unless the scales were built, maintained, tested, and operated in a thoroughly competent manner. Better no scales at all than poor ones which would only add confusion to present uncertainty.

The track scale consists of three parts: (a) the weigh-bridge on which the cars are placed, (b) the scale-beam and (c) the lever system. The multiplication of the lever arms between the scale-beam and the weigh-bridge is usually 7,000 or 10,000 to one, that is, one pound hung at the tip of the scale-beam will balance 7,000 or 10,000 lb. on the weigh-bridge. This high multiplication, combined with the requirements of extreme accuracy and sensitivity, demands experience and skill on the part of scale makers. The impact of heavy moving loads on the scale mechanism necessitates sturdy construction and conservative working stresses. Testing and maintenance demand accessibility in the scale pit. Since sustained accuracy of scales is determined largely by the degree to which moisture and dirt are excluded from the mechanism, the waterproofing of the deck and of the pit is of fundamental importance.

A track scale should give from 25 to 35 years service, so it is but reasonable that great care should be used in its selection. If a locomotive or considerable routine switching will cross the scale, a dead rail should be installed on the scale to carry such traffic.

TRACK scales are tested by both the railroads and the Bureau of Standards which make recommendations for necessary repairs. These recommendations should be carried out by competent scale repair men only. Maintenance by plant crews should be limited to cleaning, painting, and needed repair of the deck and pit.

While track scales perhaps lie outside the immediate province of the chemical engineer, it will be to his advantage to check up occasionally those used by his company, to assure himself that they are periodically tested by competent authorities and are removed from service when their error becomes excessive.

The Power Code Committee of the A.S.M.E. has asked the Scientific Apparatus Makers of America to aid in clarifying terminology on recording and indicating thermometers that depend for operation on the expansion of liquids, of gases, and the vapor tension of volatile liquids. Suggestions are desired which will simplify the present confusion arising from conflicting terms. The old names "Pressure Gage" and "Bourdon Tube" thermometers are now deemed to be misleading and individual manufacturers' efforts have not become standardized sufficiently. Any discussion or suggestions on the subject will be welcomed by *Chem. & Met.*

Novel ELECTRICAL CONTROLS *Developed* *in Making Radio Tubes*

By B. E. Shackelford
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Bloomfield, N. J.

A RADIO tube is, fundamentally, a means for converting an electrical stimulus, or input, into an electrical output which differs from the input in one or more ways. Since the broadcast listener, numerically the largest user of radio, must have a set which is the equal to that of his neighbor with respect to distance getting or sensitivity, selectivity and latterly, quality, each element in the receiving equipment must be precise and interchangeable with another similar element. It is this which makes large production compatible with the other receiver requirements mentioned. Then follow increased sales price adjustments and further improvement in a regular and repeated sequence.

There are innumerable steps in the manufacture of radio tubes where careful control, with respect to composition of material, temperature and dimensions is required. These controls are, so to speak, a means to the end that the finished product, the tube itself, may meet certain conditions or tests, and become a part of a receiving set whose task it is to meet the requirements of the user. Just as the requirements of the complete equipment circumscribe the range of characteristics of the tubes, so does the necessity for restricting this range make necessary the original controls on materials and processes. We are here concerned with the checks on the tube manufacturers' product and their use in control of the manufacture.

One tube or type of tube differs from another in dimensions and placing of parts, in primary characteristics such as: electron emission and visional gas, and in electrical characteristics resulting therefrom. Once the design is crystallized, parts and their placing checked for each tube, it is necessary to make sure that the emission and gas conditions in the tube are satisfactory and then to check one or more additional electrical characteristics to eliminate the stragglers and defects that occur during processing.

ORDINARILY a plate current reading, under given voltage conditions, is the simplest check on the uniformity of the product; for many types of tubes it is sufficient. For high amplification tubes it may be desirable to read the "amp" factor. For some types it is necessary not only to check plate current, but also mutual conductance, filament current, etc.

Primary reliance is placed on the regular factory test to see that the tubes meet the stated requirements. Each tube is tested for gas and electron emission and for such control characteristics as may be desirable.

The factory test sets, as at present used, have been the result of considerable investigation and have been determined upon only after many test designs were tried out in production.

IN THE case of tubes of large production, there have been developed automatic test machines, into which the tubes are fed from a belt and where they are tested as above and segregated into good and bad groups. Even the defects are classified to any extent desired. In one particular case the tubes are divided into four groups: good tubes, tubes low in emission or high in gas, tubes outside of plate current limits and inoperatives.

The tubes going through this test machine are carried on a rotating top, which connect a given tube first in one test circuit and then another, each test circuit being provided with the necessary meters for visual indication and the necessary relays to work solenoid trips or reject. It has been found, as anticipated, that the automatic machine has a better record for accuracy of test than have the hand operated test tables. A general idea of the automatic test equipment is given in Fig. 1.

The engineering department takes charge of the inspections and sample testing subsequent to the factory test. As the tubes pass from the factory inspection positions to the packing, an operator of the so-called "belt inspection" group selects tubes at random, testing them for the same characteristics as does the factory operator. Whenever a defect is found a large number of tubes, both before and after the defect, are tested to determine whether the defect is a casual or typical one. If the defect is found to be casual the flow of tubes proceeds as before, after the defective tube has been removed. If the defect is found to be typical, the factory testing at the position in question is stopped until the

position has been checked, after which the suspected tubes are retested by the factory and the regular flow of tubes restarted.

Although the belt inspection covers only the characteristics for which the factory is expected to test, it has been found desirable to equip the belt inspector with a test table which will take care of readings on all characteristics. This enables the inspector and the factory to maintain a better check on the special characteristics and to assist the factory in obtaining information quickly when lots with small variation of dimensions are put through for test purposes. A general idea of this test table may be obtained from Fig. 2.

Just before, or in some cases just after packing, a representative of the radio engineering department, selects at random samples of each type of tube. The selection is spread over the whole day, in order that the tubes selected may, to a certain extent, be representative of the day's production, and not be representative of any particular lot. These tubes are taken to the radio engineering department and after identification, are inspected for external and internal manufacturing defects and for electrical or characteristic defects. Readings are made, not only for the items checked by the factory and belt inspector, but for what may be called complete characteristics.

In addition to the electrical readings, a complete mechanical inspection is made on each tube. This covers such items as: overall length, length of pins, diameter of base, pin spacing, alignment of bulb and base, bulb etching, base branding, appearance of mount, loose welds, loose particles in bulb, abnormal discoloration and other appearance items.

The radio engineering department inspection is a control in a different sense from that of the factory and belt inspections. This department's reading are used to check trends of characteristics, to correct designs and to maintain the proper correspondence between the characteristics which the factory checks and the additional characteristics which are of importance in set operation.

A certain proportion of the tubes selected by this department is held in stock, part of it inspected at the end of seven days and the rest at the end of thirty days The results of this inspection are utilized for the purpose of eliminating from the warehouse stock any possible developmental defects, which are shown up by the inspection. This is accomplished by means of identification numbers on the packages which permit any particular group of tubes to be isolated.

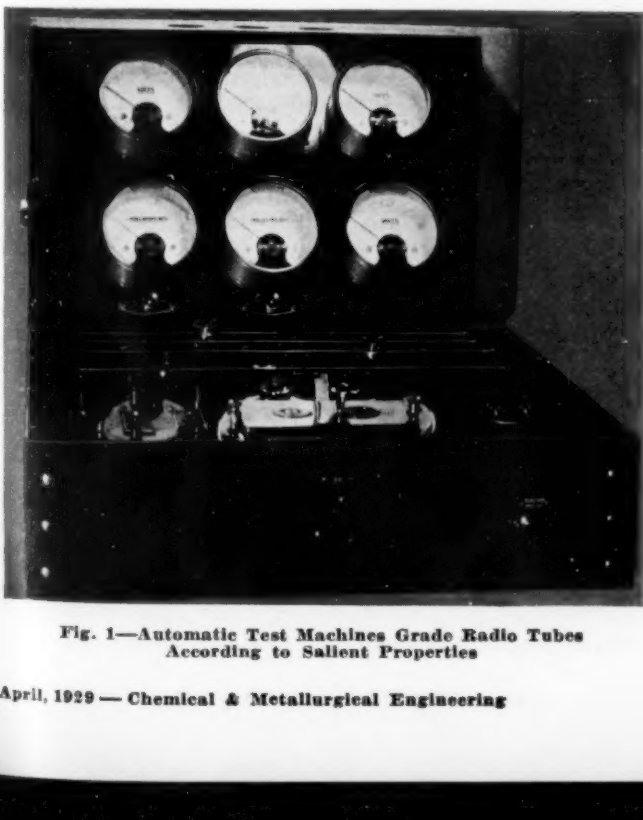

Fig. 1—Automatic Test Machines Grade Radio Tubes According to Salient Properties

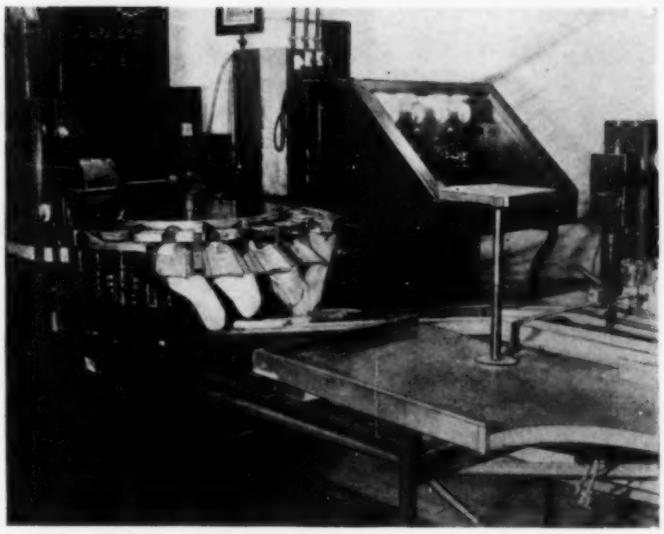

Fig. 2—Test Table Offers Check on All Characteristics

The remaining tubes selected by the department are read by the life test section and placed on burning under operating conditions or as near to these as is possible. These tubes are read at 24, 48, 96, 192, 336, 480, 696 and 1,008 hours.

DEFECTS on belt, radio engineering department and warehouse inspections are grouped into classes according to the seriousness of the defects. Class E covers inoperatives, and defects which would cause the tubes to be practically inoperative. Class D covers other major defects such as: low emission, gas, plate current and any other electrical defects and some mechanical defects, while Class B covers mainly appearance defects. Class A tubes are without scheduled defects. Weighted deductions, according to per cent and class of defects, are made from a perfect score of 1,000, this giving for belt, radio engineering department and warehouse inspections a "quality" score for each type of tube and each factory.

Daily reports of the belt and radio engineering department inspections are made to the factory superintendents.

Weekly summaries of all inspections and of life test are sent to the same group. This system places in the hands of the proper individuals complete up-to-date information on the product.

The various inspections and life scores are combined into a final factory score which is used as the basis for special monetary compensation paid to the factory supervisory force, and to those radio engineers whose period of service is above a certain minimum. This gives the engineering and factory staff a greater community of interest and responsibility and encourages better design, more thorough development and more careful manufacturing supervision. In a field growing and changing as rapidly as that of radio tube manufacture, these items are fundamental.

Manufacturing troubles indicated by the defects appearing in the various inspections are cared for by the engineering staff of the individual manufacturing division. This staff carries the front line responsibility for quality and uniformity and is aided by a service section of the general radio engineering department.

Electrical

GAS ANALYSIS

for Continuous Processing

By A. C. Schmid

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INDUSTRY in general, particularly the chemical industry, has long had need of reliable and accurate indicating and recording equipment for analyzing the percentage by volume of one gas in a mixture of gases. This demand is rapidly increasing as engineers are becoming more and more cognizant of the fact that accurate and continuous analysis equipment, incorporating control features, shows tremendous possibilities for application on processes where smoothness of plant operation, quality and uniformity of product depend on the analysis of gases. The demand for this type of apparatus has resulted in the designing of various types of continuous recorders and indicators employing chemical, mechanical and electric principles. Of these three principles the electric or Wheatstone bridge method of analyzing perhaps shows the greatest possibilities as this equipment can, with simple modifications requiring very little change in construction, be adapted to measure any number of commercial gases and can also be designed with control contacts to operate signal lights, manipulate motor-driven valves, control dampers, etc. This can only be accomplished with considerable difficulty with instruments employing chemical or mechanical principles.

The Wheatstone bridge is built into what is technically known as a thermal conductivity cell. As early as 1880 the use of the thermal conductivity cell for analyzing gases was suggested, but actual development work did not start until some years later. Science is indebted in this respect to the efforts of Schleiermacher, Goldschmidt, Koepsel, Shakespear and the more recent efforts of Palmer and Weaver of the U. S. Bureau of Standards. These authorities strenuously advocated the application of the principle on a commercial scale but manufacturers were rather slow in adapting the unit for actual plant operation because of its extreme sensitiveness and complications.

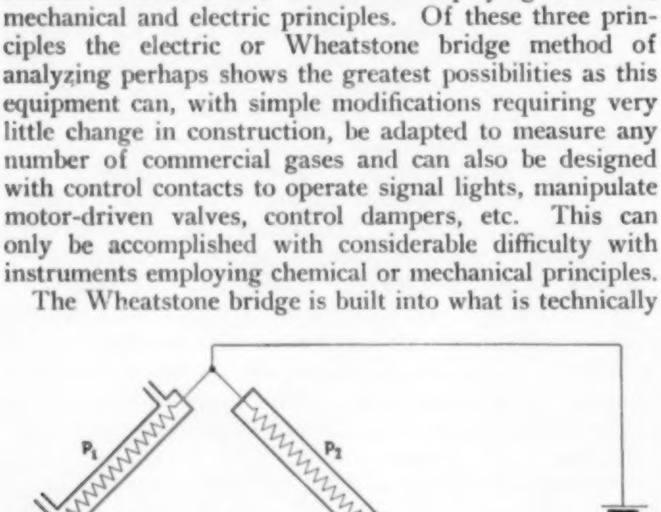


Fig. 1—Wheatstone Bridge Circuit as Used in Electrical Gas Analysis

HOWEVER, some persistent and rapid development work finally resulted in the design and construction of equipment which could be used in the average industrial plant under rather adverse conditions. As a result of this advance in design, manufacturers are placing more confidence in this type of analysis equipment as is evidenced by the increasing demand.

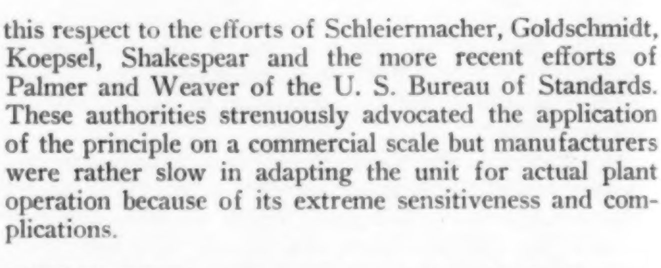


Fig. 2—Original Type of Thermal Conductivity Cell

The first thermal conductivity cells consisted essentially of the electrical arrangement indicated in Fig. 1.

The Wheatstone bridge consists of the four resistances P_1, P_2, R_1 and R_2 which form the four arms of the bridge. The two coils R_1 and R_2 have exactly the same resistance and are constructed of special manganin wire having a zero temperature coefficient of electrical resistance. The resistance of these coils is fixed, therefore, regardless of temperature changes. The other two arms, P_1 and P_2, consist of platinum wires stretched through the center of metal tubes or chambers. Platinum was decided upon because of its high temperature coefficient of electrical resistance and apparent immunity to corrosion.

DESIGN of these chambers or cells is illustrated in Fig. 2. The helical spring is attached to the end of the wire to maintain proper tension regardless of expansion and contraction caused by heating and cooling the wire.

The principle of operation is based on the fact that

practically all gases, with few exceptions, have different heat conducting capacities. The more common commercial gases and their ratios of heat conducting ability to that of air (at 0 deg. C.) are as follows:

Air	1.00
Hydrogen	7.35
Carbon dioxide	0.58
Sulphur dioxide	0.41
Ammonia	0.81
Methanol	1.31
Nitrogen	1.00
Oxygen	1.00

From these figures it can be seen that hydrogen and methanol, for example, are better conductors of heat than sulphur dioxide or carbon dioxide.

AGAIN referring to Fig. 1 the simplicity of the principle of the thermal conductivity cell at once becomes apparent. The two platinum wires, P_1 and P_2, are heated to a certain temperature by means of current from the storage battery B. For ordinary application air is sealed in the cell containing wire P_2 while the gas to be analyzed is continually passed over the wire P_1 in the other cell.

When a single gas, as for example air, or two gases having the same thermal conductivity surround the platinum wires, the bridge is in balance and the recording and indicating galvanometer G shows no deflection. If, however, a mixture of CO_2 and air is drawn over the wire P_1, the temperature and resistance of this wire will increase as less heat will be conducted from it to the metal wall of the cell due to the lower thermal conductivity of this mixture. This increase in the resistance of the wire P_1 unbalances the bridge and causes current to flow across it through the galvanometer G. In the case of CO_2 and air, this current has a definite relation to the percentage of CO_2 in the mixture and the galvanometer can, therefore, be calibrated directly in percentage of CO_2 passing over the wire.

A NUMBER of these cells were installed in the field and watched to determine their practicability and limitations. The instruments, in general, appeared to be very sensitive to any change in gas composition and required little attention to keep them in operation. However, it was found that considerable checking and readjustment was necessary in order to maintain the equipment in calibration. Although these readjustments could be accomplished easily and quickly, the calibration drift of the equipment introduced a serious disadvantage as great confidence could not be placed on the reliability of the records produced. In order to overcome this, further research was conducted to determine the cause of this calibration drift and if possible to eliminate it.

Indications pointed in the direction of contamination of the platinum wires P_1 and P_2, particularly the wire P_1 over which the gas passed. This contaminating effect apparently caused a change in resistance of the wires, resulting in a calibration drift. A series of careful laboratory checks were made involving microscopic examinations of these wires before and after the cells were put in operation. The results of these examinations, with few exceptions, indicated appreciable signs of deterioration of the wires although special care had been taken to dry and clean the gas thoroughly before passing it into the thermal conductivity cell during the tests. After the wires had been taken from the used cells, the microscope revealed a bright clean surface but the cross-section of the wire had changed appreciably. Later laboratory tests determined rather conclusively that this very apparent deterioration was due to catalytic action between the hot platinum wires and the gases, rather than a chemical reaction and that this action was more pronounced with some gases than with others.

AS this undesirable feature caused considerable trouble and limited application of this type of cell, further work was conducted which finally resulted in the development of a thermal conductivity cell incorporating the use of two quartz-protected platinum spirals. The fine platinum wire was fused between two pure fused quartz tubes, the space between the tubes then evacuated and both ends of the tubes sealed, resulting in a rigid and durable element.

The quartz protected spirals are used in the same Wheatstone bridge circuit (Fig. 1) as the bare platinum wires, but due to their construction, stability of calibra-

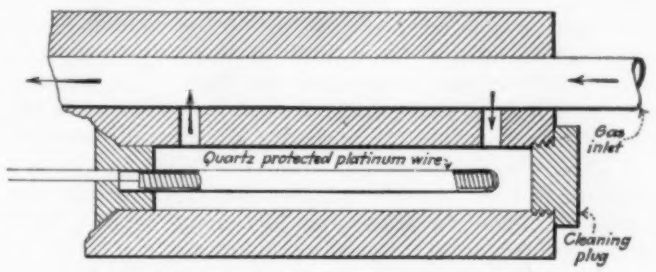


Fig. 3—Type of Conductivity Cell Now in Use

tion of the cell is assured as the gas being analyzed does not come in contact with the fine platinum. Change of resistance due to corrosion and catalytic action is, therefore, eliminated resulting in a cell capable of maintaining its accuracy indefinitely regardless of the type of gas analyzed. Fig. 3 indicates how the spiral is installed in the cell.

A number of these cells were applied in the field for the measurement of various commercial gases and the results showed no appreciable calibration drift. The units were found to be accurate and sensitive to any change in the composition of the gases. This feature is very desirable in some processes, especially where means are applied to indicate explosive mixtures, as in the manufacture of electrolytic H_2 and O_2 or to solvent vapors in air in the manufacture of pyroxylin film.

DEVELOPMENT and perfection of the thermal conductivity cell with quartz-protected platinum wires has resulted in its widespread application on very diversified processes. Some of the more common applications are mentioned below as well as the advantages resulting from the use of the equipment.

In the power plant, for example, the equipment has been successfully applied to measure the percentage of CO_2 in the boiler flue gases. A continuous sample of gas is taken from the last pass of the boiler and the percentage of CO_2 in this sample, as indicated by a continuous recorder, is indicative of the efficiency of combustion in the boiler furnace. If an excess of air is being used, the recorder shows a low percentage of CO_2 and a proportionate loss in fuel as this excess air absorbs heat that would otherwise be used to generate steam. It is obvious, therefore, that a CO_2 recorder in this

case proves itself of exceptional value inasmuch as it furnishes a guide for the fireman who knows at all times whether or not he is supplying the correct amount of air to burn the fuel with maximum efficiency.

The electric CO_2 recorder has also been applied to the products of combustion in ceramic kilns with a view to determining the efficiency of combustion as well as the atmosphere inside the kiln. In the manufacture of terra cotta ware, for example, it has been found that a change in the atmosphere of the kiln has a decided effect on the color of the ware in some instances. By obtaining a continuous record of the condition of the atmosphere inside the kiln this instability of color can be prevented to a great extent.

ANOTHER interesting application is continuous electrical analysis of SO_2 in manufacture of sulphite pulp. Sulphur is burned to SO_2 which is then cooled by passage through lead cooling pipes. From the coolers the gas passes into absorption towers, producing sulphurous acid for digesting the pulp. In this process care must be exercised in burning the sulphur since an insufficient supply of air will cause sublimation of the sulphur in considerable quantities inside the cooling pipes. This may result in an appreciable loss of sulphur as well as a plant shutdown to clean out the flues. The installation of SO_2 analysis equipment, however, will enable the burner man to make all necessary damper adjustments and avoid this contingency. He will hence have complete control of the air supply and can regulate his burner to obtain the maximum percentage of SO_2 with very little danger of sulphur sublimation.

The electric SO_2 analyzer has also been applied rather extensively in both chamber and contact acid plants. In the contact plant the measurement of SO_2 in the burner gas is very important as the sulhpur must be burned with a predetermined volume of excess air. This excess air contains sufficient oxygen to insure complete conversion of the SO_2 to SO_3 when the gas is passed over the catalyst. It is obvious, therefore, that careful control of the combustion is also essential in this process as insufficient oxygen in the entrance gases will result in a lowered SO_2 conversion, a drop in plant production and a loss in sulphur, indicated by a large percentage of SO_2 in the exit gases. This loss can be eliminated to a great extent through the guidance of a continuous SO_2 analyzer.

IN THE MANUFACTURE of synthetic ammonia also, thermal conductivity has been applied for analyzing gases. In this process it is usual to analyze the ratio of hydrogen to nitrogen before the mixture is passed over the catalyst where part of it is converted to ammonia. After conversion electric gas analyzers have also been applied to analyze the percentage of ammonia in the hydrogen and nitrogen in order to determine and control the efficiency of the converters.

The ammonia oxidation process for the manufacture of nitric acid has also created a new field for gas analyzers. In this process ammonia and air are passed over an active catalyst and oxides of nitrogen are formed. It is essential that a proper ratio of ammonia and air be used as serious losses occur which decrease the overall efficiency of the process if this ratio is not kept fairly constant. Here an electric analyzer equipped with control contacts for automatically maintaining the proper ratio proves of great value.

While these applications touch upon advantages to be derived from electrical gas analysis equipment in the major industrial processes, no mention has been made of other rarer applications where the equipment has been used extensively for special research work. It appears that this type of instrument should eventually assume much importance in the industry as there is a decided tendency toward synthetic production which, in many cases, can be accomplished by the reaction of gases.

Unique EXPANSION RECORDER *for New K.S.G. Plant*

EDITOR'S NOTE:—*At New Brunswick, N. J., the International Coal Carbonization Company, a subsidiary of the International Combustion Engineering Corporation, has just completed its K.S.G. plant which is the largest low temperature carbonization plant in the world. This plant was visited by representatives of* Chem. & Met. *on March 18 and 30, and an illustrated article describing and interpreting its operations is being prepared for publication in the May issue. One of the many features of unusual interest in the new plant is a unique type of temperature control which is briefly described here because of its bearing on the Process Control theme of this issue.*

THE NEW low-temperature carbonization plant of the International Carbonization Company at New Brunswick, N. J., presented an unusual problem in controlling the temperature in its rotary retorts. This was satisfactorily solved in a comparatively simple way by the development of an instrument that indicated and recorded the expansion of the inner and outer shells of the rotating carbonizing retorts. The differential expansion is interpreted as an index of temperature conditions on the inside of the inner shell.

As shown in the accompanying photograph, taken during construction, the carbonizing plant at New Brunswick consists of eight of the K.S.G. (Kohlenscheidungs-Gesellschaft) retorts. Each consists of two concentric drums externally heated, inclined slightly from the horizontal and rotated at three-quarters of a revolution per minute. The outer drum is 75 ft. long with a 10-ft. diameter, while the inner is 85 ft. long with a $5\frac{1}{2}$-ft. diameter. The entire retort weighs about 160 tons and was so constructed that no other means were available by which a satisfactory record could be obtained for the temperature of the inner shell.

The double-expansion recorder, developed by the Shallcross Control Systems Company of Milwaukee, comprises two units:

(1) The expansion detector consists of the bar "B" supported horizontally between rollers. At one end of the bar is mounted a steel roller "A" which rides against the revolving shell and is held against it at all times by coun-

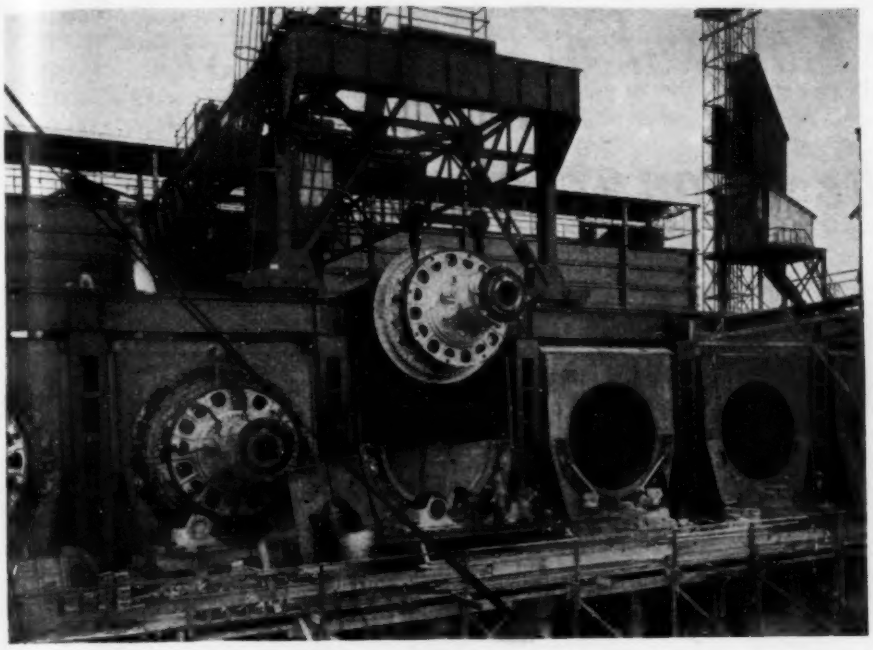


Fig. 1—A View of the New K.S.G. Carbonizing Plant Taken During Construction and Showing One of the Huge Rotating Retorts Being Placed Into Position
Each of these retorts weighs approximately 160 tons and has a rated capacity for carbonizing 80 to 100 tons of coal per day.

World's Largest Low Temperature Coal Carbonization Plant

The New Brunswick K.S.G. plant, with an annual capacity of nearly a quarter of a million tons of coal, is the largest plant that has yet been built for low temperature carbonization. The original installation of the Kohlenscheidungs-Gesellschaft has been in operation at Karnap, near Essen, Germany, for the past five years. Both plants are owned and operated by subsidiaries of the International Combustion Engineering Corporation.

From each ton of coal there are obtained about 1,500 lb. of semi-coke, 25 gal. of tar, 3,500 cu.ft. of rich coal gas (about 900 B.t.u. per cu.ft.) and 2 to 3 gal. of light oil. About 80 per cent of the semi-coke is recovered in salable sizes.

terweight W-1. Each shell has its own expansion detector which is connected to the recorder unit by a very flexible cable of Monel metal.

(2) The recorder unit consists of two pen bars "E" supported vertically between suitably mounted rollers. There is one pen and pen bar for each expansion detector. The cable from the dectector makes a quarter lap around pulley "B" and fastens to the upper end of the pen bar. To the bottom end of the pen bar is fastened another flexible cable running up and over the top of pulley "D" and down to counterweight W-2 which supports the weight of the pen bar and pen and

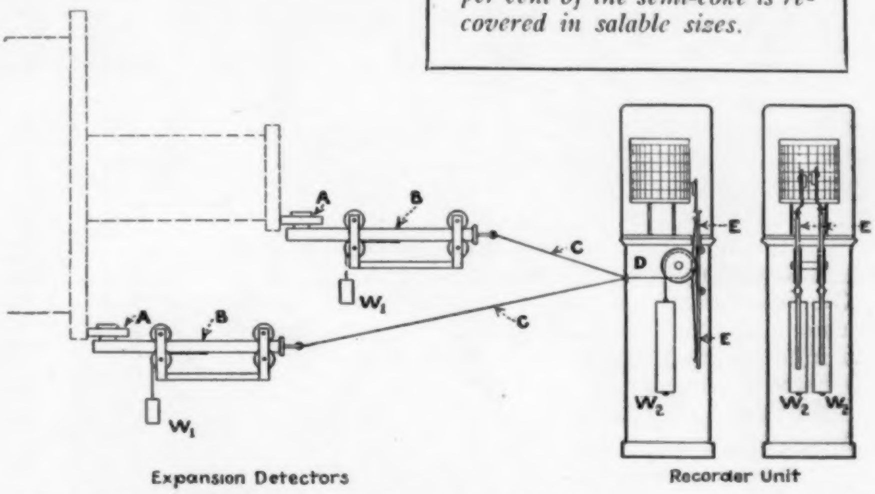
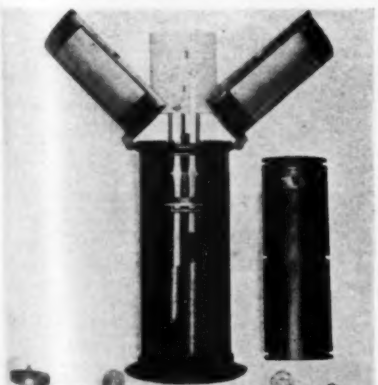


Fig. 2—Diagrammatic View of Shallcross Recorder Developed for Indicating and Recording the Difference in Expansion of the Inner and Outer Shells of the Rotating Retorts
This differential expansion gives a convenient index of operating conditions within the inner shell of the retort.

Fig. 3—Double-Expansion Recorder and One of the Roller Bars For Detecting Expansion of Shells



also holds the connecting cable "C" taut at all times. In the upper half of the recorder is mounted a 24-hr. clock revolving a drum around which is fastened a rectangular chart. This chart is calibrated in hours on the vertical division, and in inches on the horizontal divisions. The pens are mounted at an angle so that the record of the expansion of both shells of the carbonizing retort is recorded simultaneously on the same time line.

The operation of this expansion recorder is such that if the expansion of either shell increases or decreases, connecting cables "C" move exactly with the expansion which, in turn, raises or lowers the pen bar. There is no amplification of motion in the movement; i.e., 1 in. expansion of the shell causes the pen to move exactly 1 in. also. Weight W-2 acts as a reactive effort and moves the pen upward on the chart as the expansion increases. A decrease in expansion of the shell brings weight W-1 into effect to pull against weight W-2 and thus pull the pen and pen arm down, maintaining the roller at all times in contact with the shell of the carbonizer or the retort.

Because the entire recorder is of such comparatively simple construction it is practically fool-proof and requires no adjusting.

Automatic Control of Electrolysis in the Production of CAUSTIC SODA

By H. D. James

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Demand for chlorine and caustic soda by the paper industry of the Northwest caused the Hooker Electrochemical Company of Niagara Falls, New York, to erect a plant for the manufacture of these chemicals at Tacoma, Washington.

The novel feature of this plant is the automatic control of the current passing through the solution of sodium chloride for separating it into chlorine and caustic soda. Automatic control had been attempted before with limited success but difficulty was experienced with the "hunting" of the regulator, which would over-shoot and result in unstable operation. This problem has been met by a very ingenious arrangement of differential coils on the controller that regulates the current. The operation of this controller will be explained later.

The installation consists of two 1,500-kw. booster synchronous converters taking their power through transformers from the central station power system. The current delivered by the rotary is maintained at a constant value by regulating the shunt field of the booster by means of a motor-operated field rheostat. The rotary will give a total voltage range of 230 to 310 volts by making the proper adjustment. It is set for a definite current by adjusting the connections between the controller coil and a permanent resistance connected in series with this coil. Fine adjustments are obtained by means of a spring.

A power-factor control is used to maintain unity power factor. A voltage regulator prevents the rotary voltage from building up beyond a fixed value if the resistance in the circuit of the rotary armature is temporarily increased so that normal current will not pass through this circuit.

The operation of the electrical equipment is shown by Fig. 1, which is a simplified diagram of this installation. The rotary armature is connected directly to the electrolytic cells, the current passing through the armature, the interpole field windings "I," compensating series field winding "S-3" and the electrolytic cells back to the rotary armature. Each shunt field has a separate motor-operated rheostat in series with its windings. The motors for operating these field rheostats are shown on the right hand side of the diagram. The armatures are marked with the letter "P" and the shunt fields are permanently connected to the power supply.

The coil "A" of the current controller is connected in shunt to the interpole field winding "I" through a resistance. This resistance is provided with taps so that it can be changed to adjust the current setting of the controller. The controller magnet operates two contacts shown as "R" and "L" in the center of the diagram. These contacts connect the circuits to two coils marked "RC" and "LC." These coils operate small contactors having "up" and "down" contacts. In the normal position with contacts "R" and "L" opened, the bottom contacts shown as No. 2 and No. 4 on the diagram are

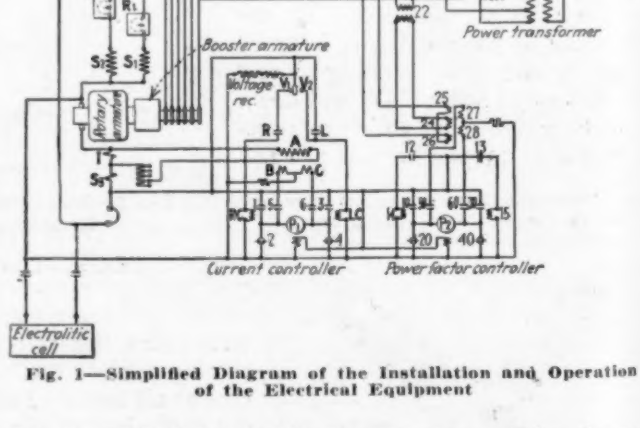


Fig. 1—Simplified Diagram of the Installation and Operation of the Electrical Equipment

closed. This short circuits the armature of the rheostat motor and stops its rotation very quickly.

Let us assume that the current to the electrolytic cells drops below normal. The current controller will close contact "R" which energizes coil "RC" closing contacts Nos. 1 and 5 and opening contact No. 2. Current now passes through the field rheostat motor armature "P1" and causes it to move the field rheostat "R1" in the direction to increase the voltage of the rotary. The rheostat motor first operates continuously but when the rheostat approaches the condition where the current value is nearly correct the anti-hunting device causes the motor to have an intermittent motion that moves the rheostat very slowly. When the rheostat reaches the

correct position, this intermittent motion ceases and contact "R" remains open.

The anti-hunting device on this controller consists of two auxiliary coils shown as "B" and "C" on the diagram. When contact "R" is closed it energizes coil "B" through contact No. 5; this coil opposes coil "A." When the current approaches the correct value, the strength of coil "A" is reduced sufficiently to be neutralized by coil "B," this opens contact "R" which opens No. 1 and 5 and stops the pilot motor. Contact No. 5 disconnects coil "B" and permits coil "A" to again close contact "R." This in turn energizes coil "RC" and closes contacts No. 1 and No. 5 and opens No. 2 starting the pilot motor and energizing coil "B." There is a small magnetic lag in all of the coils so that the relay remains closed long enough to move the rheostat a short distance. The length of time the relay remains closed depends on the strength of coil "A." Each time that coil "B" neutralizes coil "A" the relay drops open and the process is repeated until the current reaches the correct value.

When the current through the electrolytic cell is more than that for which the current controller is set, contact "L" is closed which energizes coil "LC," closing contacts No. 3 and No. 6 and opening No. 4. This operates the rheostat motor in the opposite direction to lower the voltage. Contact No. 6 energizes coil "C" which opposes coil "A" and causes contact "L" to open when the current approaches the correct value. The relay is then alternately opened and closed as described above until the current has been corrected.

The voltage regulator consists of a coil in series with the resistor which actuates contact "V-1" and "V-2." Contact "V-1" is normally closed. If the line voltage exceeds a pre-determined value, the voltage regulator coil opens contact "V-1" and stops the pilot motor "P." If the voltage continues to rise contact "V-2" is closed which energizes coil "LC" and operates the field rheostat in the direction to lower the voltage to its normal

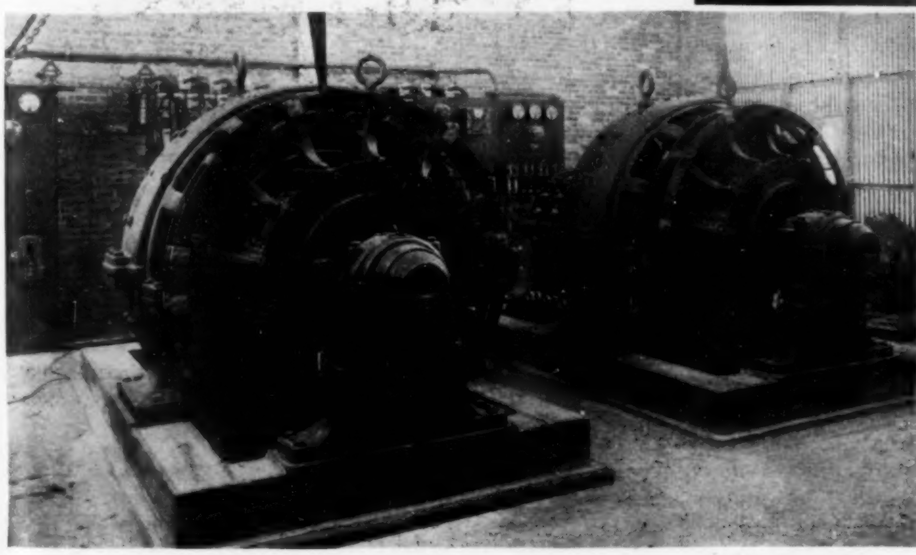


Fig. 2—Two Rotaries from D.C. End With Switchboards Partly Erected in Rear

value. When the voltage has been corrected, contact "V-2" opens, a further drop in voltage closes "V-1."

In the actual controller there are additional switches and coils which are necessary for practical operation. The field rheostat is provided with limit switches which stop the pilot motor at either limit of travel. The contactors which operate the pilot motor have additional coils to maintain the contacts No. 2 and No. 4 closed when coils "RC" and "LC" are not energized. It requires considerable experience and engineering skill to proportion these various coils and devices but the addition of the coils to the diagram complicates the connections and does not assist in understanding the operation of the device as a whole.

There are other refinements in the regulating instruments, for example, the coarse adjustment of the current controller is made by changing its coil connection to the resistor in series with this coil. The fine adjustments

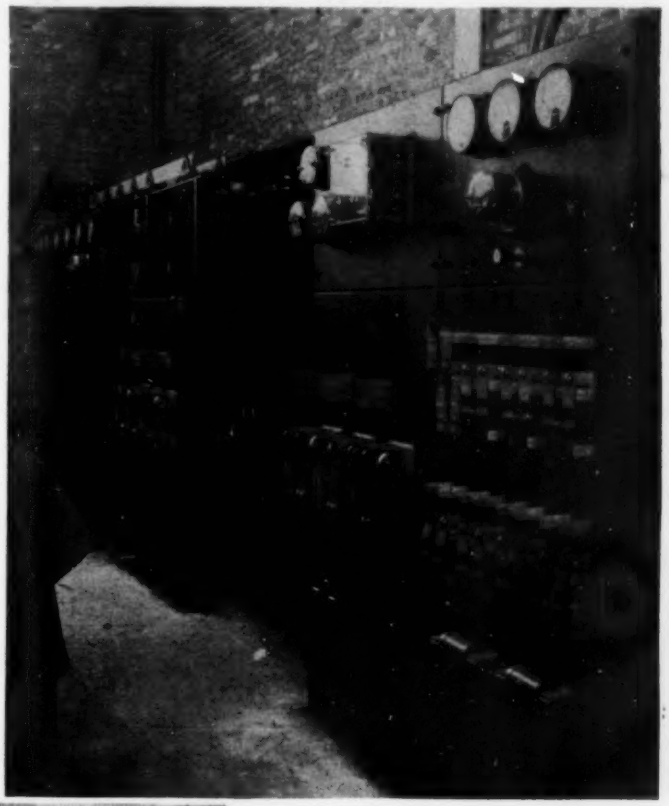


Fig. 3—A.C. Switchboard with One Regulator in Place, also Motor Switchboards and Lighting Switchboards. Other Top Panel Missing

are made by a thumb-nut located on the outside of the controller case. Turning this nut changes the tension on a spring which gives very fine adjustment to the current value at which contacts "R" and "L" close. The voltage drop across the interpole field is small and it is therefore, necessary to make all of the connections to the current controller coil in a very substantial manner. This is why the coil connections to the resistor are clamped instead of being changed by some form of commutating switch.

The power factor regulator shown on the right hand side of the diagram operates in a similar manner to the current controller. The regulating instrument consists of a central coil No. 24 energized from a shunt transformer No. 22 and two outside coils No. 25 and No. 26 connected to oppose each other and energized from a series transformer No. 21. These three coils operate on a movable part of the magnetic circuit located in the

center of the coil No. 24. When the power factor is 100 per cent, the resultant pull on this magnetic member is zero. When the power factor lags or leads, the coils exert a pull on the magnetic member which closes contacts No. 12 or No. 13. If No. 12 is closed, coil No. 14 is energized closing contacts Nos. 10 and 50 and opening

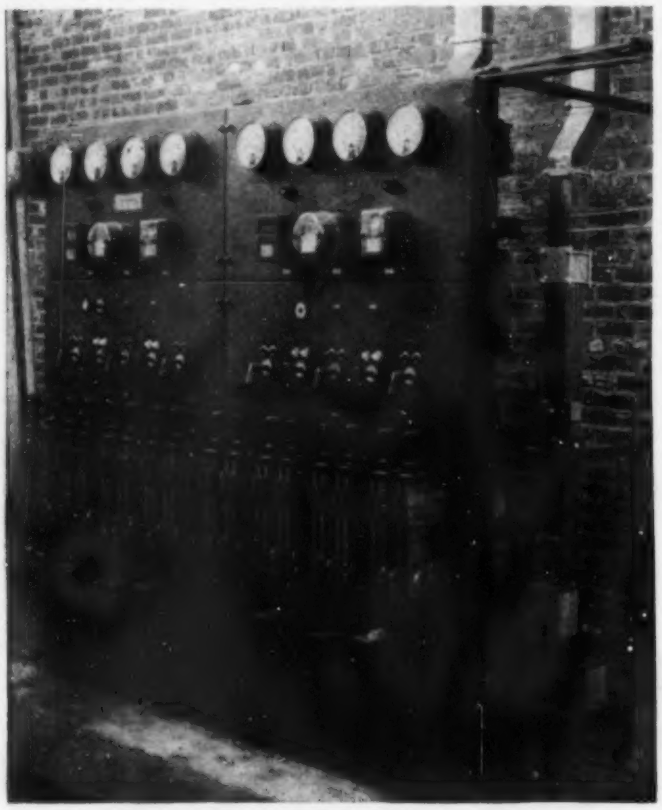


Fig. 4—Half-Front View of D.C. Switchboard Showing Bus Bars

No. 20. This causes the pilot motor "P-2" to operate the field rheostat "R-2" in the proper direction to correct the power factor. As the rheostat reaches the correct position the anti-hunting means causes the contact No. 12 to alternately open and close moving the rheostat very slowly. When the power factor is corrected contact No. 12 remains open. The opposite change in power factor operates contact No. 13 in a similar manner.

The anti-hunting means on the power factor controller consists of coils No. 27 and No. 28. When contact No. 12 is closed coil No. 27 is energized through contact No. 50 and opposes the pull on the movable part of the magnetic circuit so that contact No. 12 is opened before the power factor has been entirely corrected. This opens contacts No. 10 and No. 50 and closes No. 20 stopping the motor. As soon as No. 27 is deenergized, the power factor controller closes contact No. 12 which in turn closes the relay contacts No. 10 and No. 50 and opens No. 20. This causes the pilot motor to move the rheostat a small distance. Coil No. 27 again functions to open contact No. 12 and stops the pilot motor. The operation is the same as the anti-hunting means on the current controller. If contact No. 13 is closed, coil No. 28 is connected in circuit and causes contact No. 13 to be opened before the power factor is entirely corrected. The operation is the same as just described for coil No. 27.

A switchboard shown in Fig. 4 controls the circuit between the rotary and the electrolytic cells and also provides for mounting the control equipment. The necessary circuit breakers and switches are provided so that either rotary may be connected to the load and have the necessary automatic protection against accidental circuit conditions. The transformers for supplying power to the rotaries are connected to the power circuit through high tension circuit breakers and the necessary disconnecting switches. The various switchboard connections are the same as are common for similar installations and are, therefore, not described in detail.

The manufacturing process is continuous. The chlorine gas is piped to the proper containers and the

Fig. 5—Half-Rear View D.C. Switchboard Showing Bus Bars

caustic soda solution is drawn off automatically. The sodium chloride solution is maintained at a constant level by means of a float in an adjacent tank. The rate at which chlorine and caustic soda are separated depends on the current which is regulated as described above. The whole process is, therefore, continuous and automatic and requires very little supervision.

Chemical Control in Steel Industry

The United States Steel Corporation, according to W. A. Forbes, assistant to president James A. Farrell, operates 179 chemical and physical testing laboratories employing a staff of over 2,000 technical men and women. Forbes stressed the fact that the industry is dependent upon these laboratory workers to render it still more efficient in quality of product, in minimizing waste and in enlarging the commercial diversification of all of its products.

INSTRUMENTS

That Simplify Process Control

IT IS A TRUISM, *perhaps, to state that accuracy of process control depends upon the exactness with which the variables that enter into it can be measured and controlled. Nevertheless, it is a truism which is worth the repeating, for its importance cannot be overestimated.*

There is no single place in the literature today where an attempt has been made to bring together information on the control of all, or even a considerable number, of the major physical and mechanical variables that enter into chemical processing. Chem. & Met. *has not had the temerity to attempt a program as ambitious as the first alternative, but an effort has been made to assemble data regarding the instruments that may be had to assist in controlling a considerable number of these variables. Some of the equipment is for measurement only, as a gage for manual operation, while much is fully automatic. The type to use will depend upon circumstances.*

Free use of the literature has been made as well as of the generous assistance given by the many instrument makers whose equipment enters into the discussion. To all these Chem. & Met. *expresses appreciation.*

Temperature Control

MEASUREMENT of temperature for the controlling of heating or cooling agents manually or automatically, and perhaps also for the graphic recording of temperature cycles in apparatus, is today the most varied field in industrial instrumentation. This is a fact not only because temperature control, particularly in the chemical engineering industries, has broader applicability than other sorts of control, but because it is susceptible, in itself, to enormous variation.

Temperature Measurement Classification.—In general, temperature control is handled with one of three types of instruments, each of which is outlined graphically in considerable detail on the following page. The class referred to as thermometers is generally considered to cover the range up to 1,000 deg. F. Pyrometers range from 1,000 deg. F. to the highest temperatures measureable. Each of these may also include the feature of automatic control but a third class of instruments, temperature regulators, is usually understood to refer to those devices which control without giving a visible indication of the magnitude of the temperature being controlled.

This classification is not rigid as it will appear that certain classes of thermometers (resistance) are satisfactory to 1,800 deg. F. while thermo-electric pyrometers may be used at temperatures near the absolute zero as well as for the medium high range.

Expansion Thermometers. — Thermometers are either actuated by the expansion of some material placed in the zone it is desired to examine, or by the change in electrical resistance of a metallic conductor. Expansion thermometers may be of the fluid-in-glass type, which is generally familiar and will not be considered here, or they may make use of the differential expansion of two solids, usually metals, or of a solid container and a fluid. Most industrial indicating and recording thermometers are of the latter type.

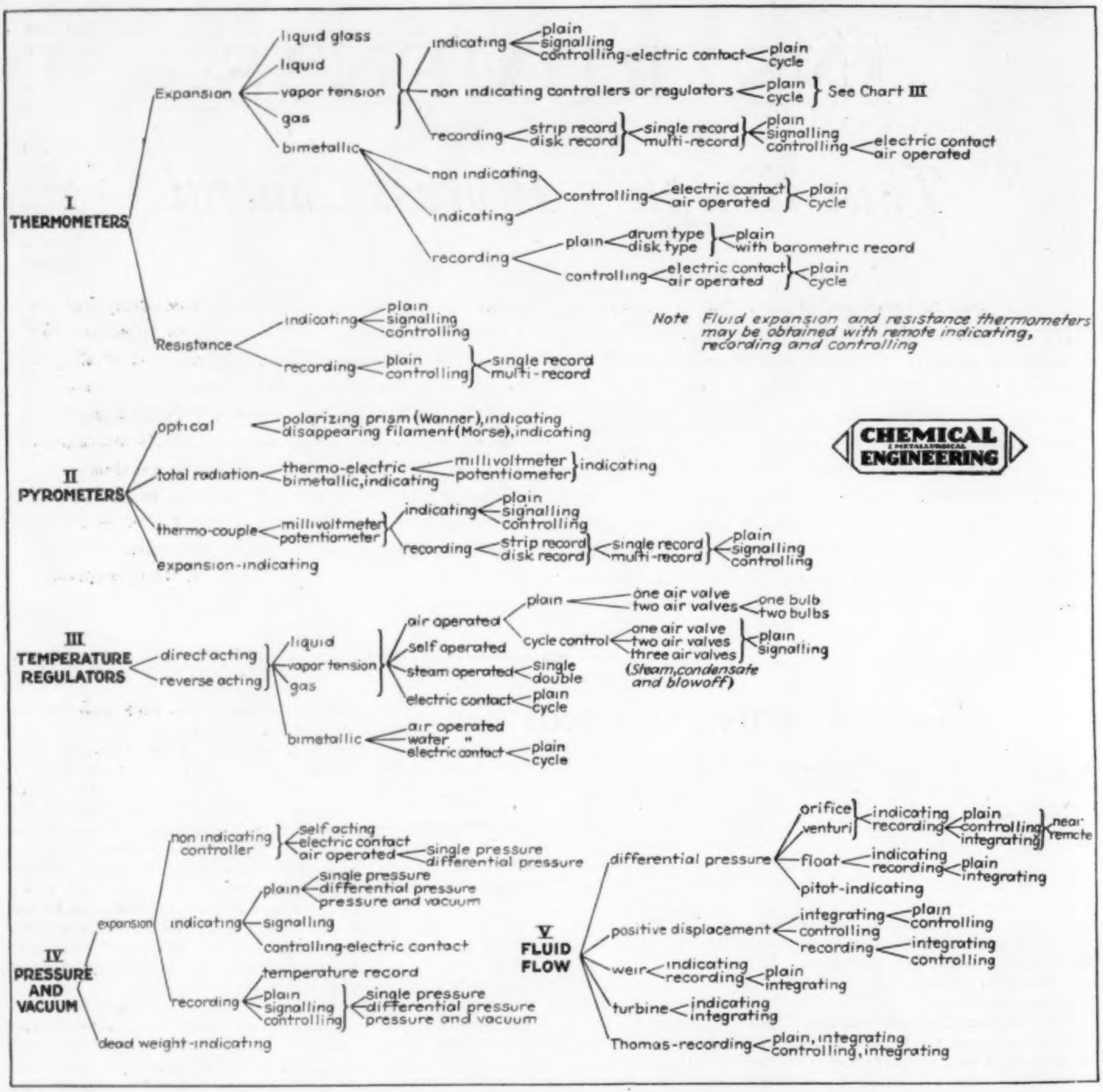
Fluid actuated thermometers ordinarily make use of the expansion of mercury or of an inert gas (usually nitrogen) or employ the change of vapor tension of a liquid contained in a bulb in the measured zone. Changes in pressure of the fluid act upon some form of pressure-responsible element, changing its dimensions so as to actuate an indicating or recording mechanism. This element consists of some form of flexible metal capsule or bellows or a coiled tube which tends to coil more or less tightly with changes in pressure. The tubes used are similar to the usual bourdon tube or, to gain length and consequent greater movement for a given temperature change, the tube may be made in the form of a spiral or helix.

Mercury-actuated thermometers are obtainable in the range from minus 40 deg. F. to 1,000 deg. F. where the distance between the sensitive bulb and the indicator is not great (usually under 50 feet). For greater distances, the effect of temperature variations along the connecting tube must and can be compensated. Most usually, however, a vapor tension or gas thermometer is used in such cases. These are applicable up to 500 ft. between the bulb and the instrument.

The former can be had in ranges from 20 deg. to 750 deg. F. It has the disadvantage that the temperature scale is compressed in the lower ranges and expanded in the upper. (Some makes compensate for this variation by means of a cam or spring). However, the disadvantage may become an actual virtue in cases where an open scale for higher temperature is desirable. In this type of instrument such liquids as ether, sulphur dioxide, methyl or ethyl chloride may be employed.

The gas-filled thermometer, has a disadvantage in requiring a considerably larger sensitive bulb than either of the thermometers previously described. However, it has, like the mercury instrument, an equally divided scale and a range from minus 40 deg. to 1,000 deg. F. with the further advantages of remote indication up to 500 ft. and a light and flexible actuating system.

Styles of Expansion Thermometers.—These types of fluid actuation are used both in indicating and recording thermometers. The former consists usually of a pointer traveling over an easily read dial. Such thermometers are used where an inexpensive instrument suffices, where visibility is a requisite and the recording feature is not needed. They may be obtained with two pointers to show two temperatures upon a single dial, as for example the temperature of water entering and leaving a condenser. Or they are available with adjustable electric contacts for control or signalling purposes. Some instruments use a capillary connecting tube of considerable length, while in others the bulb is attached within a few inches of the indi-



Above is an Outline of the More Common Types of Instruments for Indicating, Recording and Controlling Temperature, Pressure and Flow

cator for mounting directly upon the apparatus.

Recording thermometers are used wherever a permanent record of temperature variation is necessary. Records are marked in ink with a pen or traced with a stylus upon a smoked surface. The latter is usually reserved for recording variables other than temperature where very rapid fluctuations are to be followed. Records may be marked upon circular charts, showing duration of one day to one week. Or a strip type chart, of one month or more duration, may be used. Occasionally a drum-shaped holder is employed, using a rectangular chart.

Obviously, the characteristics of the chart used determine the appearance of the instrument. Mechanism, however, is substantially similar for all. The variables consist mainly in refinements, in the actuating system as previously discussed, and in the clock movement. Clocks may be either hand wound or they may be electric driven. In the latter capacity, the Warren synchronous motor clock is ordinarily employed. It eliminates the variable of adjustment and the vagaries of hand winding.

Recording instruments are obtainable in self-contained types for measuring atmospheric temperature; with directly attached bulbs for mounting, for instance, on the outside wall of a drier; or with remote bulbs. They may be supplied with multiple recording systems for several temperatures or with air valves or electrical contacts for control purposes. The latter features will be described in connection with control instruments.

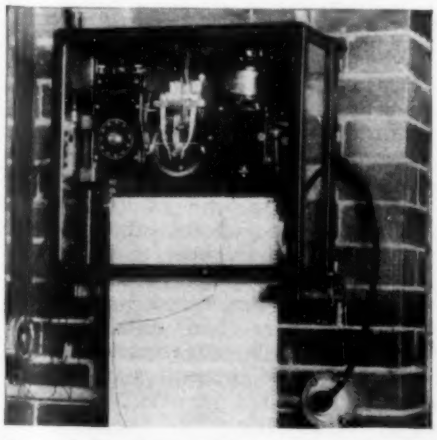
In addition to fluid expansion thermometers there is a class of instruments which makes use of the difference in expansion of two solids, as for example copper and manganin. These elements may be attached to each other for their entire length, in which case a temperature change results in a bowing or coiling action. Or the change may be linear through placing one element within the other, as a copper rod within an iron tube. If the two are attached at one end, a differential motion is obtained at the other. It is evident that this type of instrument cannot be used for remote indicating without some special system of transmission.

Such bimetallic thermometers have been used for indicating, recording and control purposes. Without the indicating feature they are used in air- and

Tycos Heavy-Case Recording Thermometer in Gas Plant

water-operated controllers. As indicating thermometers they may in addition be fitted with contacts for signalling and controlling. One type uses a drum chart and supplies also a record of barometric pressure.

Resistance Thermometers. — Resistance thermometers complete the thermometer division of temperature measuring instruments. They are not only capable of the greatest accuracy, but they are also usable through the widest range of any type of thermometer. On the other hand, in many instances the greater cost of this type of instrument is not justified by its greater accuracy. Here another consideration enters, however, for if the temperatures to be measured do not fluctuate rapidly, it is possible to make as many as 16 different records on one chart—or when using an indicating instrument, to switch consecutively an even greater number of thermometers to the one indi-

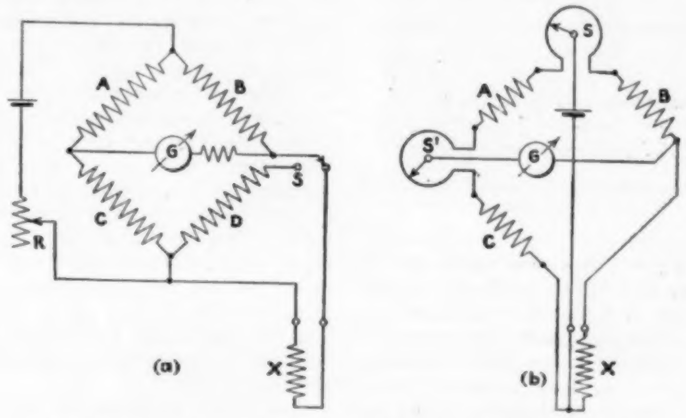


Leeds & Northrup Temperature Difference Recorder Which Uses Two Resistance Thermometers

cator. Under these circumstances the total cost of an installation of resistance thermometers may be considerably less than that of an equivalent number of thermometers of other types. In addition, resistance thermometers may be located at any reasonable distance, up to say half a mile, from the recorder or indicator.

Resistance thermometers, briefly, consist of a coil of wire of relatively high temperature coefficient of resistance, placed in one arm of a Wheatstone bridge circuit. Measurement of change in resistance of the coil or of deflection of the galvanometer may be used to denote change in temperature. Both methods are used in practice.

The thermometer elements or "bulbs" are usually wound of platinum, nickel or copper wire. Two types of circuit in which the resistance bulbs may be placed are illustrated diagrammatically in the accompanying figure. Sketch (a) shows the circuit employed by the majority of makers of this type of equipment. This system uses fixed resistances in the network and takes galvanometer deflection as the measure of temperature change at the bulb *X*. *C* and *D* are respectively equal to the resistance of *X* at the lowest and highest temperature. By switching *D* into the circuit the resistance *R* may be ad-



Two Types of Circuit Used for Resistance Thermometers
An unbalanced Wheatstone bridge appears in (a) while (b) represents a balanced circuit

justed as often as necessary to give the proper battery voltage.

Sketch (b) shows the network used in the Leeds & Northrup instrument. This circuit is of the "null" type wherein the galvanometer is brought to zero by adjustment of the two slide wires *S* and *S'*. Such a system eliminates the effect of voltage fluctuation and is somewhat more accurate. Adjustment of the slide wires is accomplished automatically in a very ingenious manner. As the same balancing feature appears in several other Leeds & Northrup circuits, it will bear description.

The balancing mechanism is powered by the small synchronous motor which runs the strip chart. Periodically, at short intervals, a chopper bar ascends and strikes a needle attached to the movable galvanometer coil. If the coil is in balance, nothing occurs. If the needle is deflected to one side or the other it is caused to strike one of a pair of levers to rotate a disk by means of a clutch. Attached to the disk is a drum carrying the two slide wires *S* and *S'*, each in contact with a fixed brush.

If one movement of the disk suffices to balance the bridge, the next motion of the chopper bar is without effect. Otherwise, the action continues until the balance is established. The amount of rotation of the slide wires determines the location of the recording pen and hence gives the temperature indication. If a control function is to be included, rotation of the slide wires makes or breaks electric contacts in the control circuit.

While no special leads are required with resistance thermometers, one possible source of error lies in the variation of resistance of the leads due to temperature. One method much used to obviate this is the three-wire system illustrated in sketch (b) as compared with the two-wire system in (a). It is obvious that, if the leads are of subsubstantially equal resistance, equal changes will occur in both the *X* and *C* branches of the network, resulting in no change of balance.

Resistance thermometers may be used to obtain the average temperature of several points by use of several bulbs in series. Or, if an additional bulb is placed in the network instead of the *C* resistance, the temperature difference between the two bulbs may be accurately measured.

Recording resistance thermometers usually employ strip charts and electric clocks. Controlling or signalling contacts may be incorporated if necessary without impairing the accuracy of the instrument.

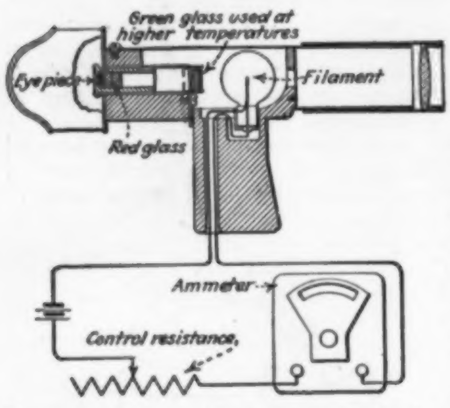
Pyrometers

There are five types of pyrometer in common use. The simplest, the fusion pyrometer, is represented industrially only in the pyrometric (Seger) cones—a series of small pyramids of refractory materials with compositions so adjusted as to have fairly predictable softening points. Cones may be obtained covering the range from about 2,100 deg. to 3,700 deg. F. in steps of about 36 deg. The use of cones is not to be recommended where anything approaching accuracy is required, although they are of assistance as a rough check.

Another type of no great accuracy and relatively small application is similar to the bimetallic expansion thermometer. It usually employs iron and carbon for the two differential expansion elements

and is not generally used much above 1,000 deg. F.

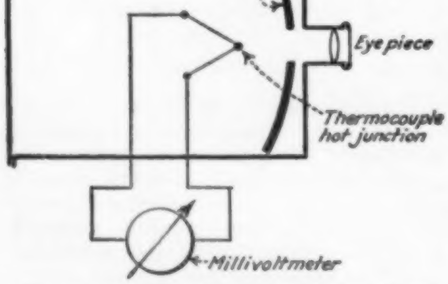
Two types of pyrometer, used for the very high range above the limit of thermocouples (2,700 to 2,800 deg. F.) measure all or part of the radiation of bodies above a red heat. These are the optical and radiation pyrometers and depend for accuracy of results upon the approach to true black body conditions of the object sighted. Fortunately, most objects within furnaces will approximate this condition closely. The optical pyrometer measures a band of visible monchromatic radiation and can



Morse Type Optical Pyrometer Made by Leeds & Northrup

be made to give surprising accuracy. In instruments of 1,400 to 5,000 deg. range, an accuracy of 5 to 10 deg. has been obtained. The radiation pyrometer, on the other hand, measures total radiation and is somewhat less accurate, even under the best of conditions. This instrument ordinarily has a range of about 1,000 to 3,600 deg. F., and gives a usual accuracy of 20 to 30 deg.

Optical Pyrometers.—The optical pyrometer is most often used in one of two forms, the Wanner polarizing type and the Morse (or "F and F") disappearing filament type. The Wanner operates by comparing the intensity of



Féry Type Radiation Pyrometer Made by Taylor

polarized light from a standard lamp and a radiating source. Disappearing filament pyrometers interpose an electric lamp filament between the eye piece of a telescope and the radiation from a luminous source. A filter is used to secure monochromatic light. Adjustment is then made so that the brightness of the filament equals that of the luminous source. In the Morse type, illustrated in an accompanying drawing, the filament current is varied until the filament seems to disappear. The measure of the filament current, as indicated by an ammeter, is proportional to the temperature of the source. The F. and F. pyrometer is similar except that the filament brightness is maintained constant and the brightness match is obtained by absorbing more or less of the radiation from the luminous source in a glass wedge of variable thickness. Position of the wedge is a measure of the temperature of the source.

Radiation Pyrometers.—The chief limitation of the optical pyrometer is that no system is commercially available for the automatic recording of temperature by its use since the eye must be the judge of brightness. The radiation pyrometer surmounts this difficulty. Here the total radiation from the emitting source is focused on the hot junction of a minute thermocouple and the potential set up is measured by an indicating or recording millivoltmeter or potentiometer. The Féry type, as made by Taylor, and shown herewith, employs a variable-focus concave mirror, while the Thwing type, a fixed focus instrument, uses a conical mirror for focusing radiation upon the couple. The "Pyro" made by the Pyrometer Instrument Company, and the "Ardometer" made by Bacharach each focus by means of a lens and use a thermocouple sealed in an evacuated glass tube. The former has the additional feature of mounting the millivoltmeter as an integral part of the instrument.

One other variation of the radiation pyrometer principle should be mentioned. This is the K. & S., a self-contained instrument which focuses total radiation upon a bimetallic spiral. Rise in temperature tends to uncoil the spiral, moving a pointer on a scale.

Thermocouples. — The greatest part of the load of high temperature measurement is carried by thermocouples. If the junctions of two dissimilar metals, connected at the ends to form a loop, are maintained at different temperatures, a potential difference is set up causing a current to flow. This emf. may be measured by means of a millivoltmeter or a potentiometer connected across the cold junction. The latter may be somewhat more accurate, but is also the more costly. Millivoltmeter accuracy is generally sufficient for industrial use.

Thermocouples may be composed of base metals for the lower ranges, and of noble metals for the higher. The most commonly used couples and their approximate upper ranges are as follows:

	Deg. F.
Copper—Constantan	1,000
Nichrome—Constantan	1,600
Iron—Constantan	1,600
Chromel—Alumel	2,200
Platinum—(Platinum-Rhodium)	2,800*

*3,000 deg. occasionally.

These ranges are variable, depending to some extent on the type of protection tube used. Within the temperature

Wilson-Maeulen Pyrometer Recorder Measuring Temperature of Electric Furnace
Pyrometer controllers at the right maintain the furnace temperature

range each should give good results. Proper selection of the couple mounting and protection tube is to be stressed, however, and should be carefully made from the large variety available. Manufacturers' recommendations are generally conservative and may be accepted without hesitation.

As yet there has been no thermocouple developed for entirely satisfactory continuous service above 2,800 or 2,900 deg. F. The noble couple may be used only for intermittent service at 3,000 deg. Work is being carried out to develop couples for higher service, however, as exemplified by the tungsten-graphite couple described by Watson and Abrams of the General Electric Company at the September, 1928, meeting of the American Electrochemical Society. Although development had not been completed, the couple gave evidence of satisfactory operation at about 3,100 deg. F. and at 3,360 deg. in the vacuum furnace. It was used intermittently to 4,350 deg. in the latter service.

Pyrometer Indicators.—As was stated above, the emf. set up in thermocouples may be measured by means of millivoltmeters or by potentiometers. The former is used by the majority of manufacturers of industrial equipment. The meter consists of a d'Arsonval galvanometer, calibrated for a particular type of couple in terms of temperature. High resistance instruments are most frequently used in order to reduce the effect of lead resistance variation. Low resistance galvanometers are more sturdy, however, and suitable where high accuracy is not required. Some instruments use means for compensating line resistance variation.

Where potentiometers are used, the galvanometer may be of the deflection or the null type. A potentiometer consists of a network in which two circuits, the battery circuit and the thermocouple circuit use one arm jointly. Potential drop in the common arm due to the battery may be balanced against that due to the couple so that a galvanometer in the couple circuit will indicate no current flow. This is the null system and makes use of a slide wire which is calibrated, usually in degrees of temperature, and is adjusted to effect the balance. If galvanometer deflection is to

Cambridge Surface Pyrometer Measuring Temperature of Paper Machine Drier

be used as the temperature measure, no balance is attempted. This latter system is used in the Wilson-Maeulen pyrometer controller. Both are applied in portable instruments while the former is used by Leeds & Northrup in an automatically adjusted recorder.

Cold Junction Compensation.—Accuracy in the use of thermocouples, regardless of the indicating system, requires some form of cold junction compensation or regulation. The emf. of a thermocouple depends upon the difference in temperature of its two junctions. It is, therefore, necessary to maintain the cold junction temperature constant or to correct for its variation. The cold junction, that is the point at which the thermocouple is connected to its lead wires, is not normally at the indicating mechanism. It may, however, be brought to the instrument by the use of "compensating" or extension leads consisting of the same metals used for the couple or metals with similar thermo-electric characteristics. Practically all systems use these extension leads. Some makers bring the cold junction to the instrument. Others place it at some point where substantially constant temperature maintains. This is usually resorted to when the leads must be long.

Use may be made of a water-cooled or steam-heated junction box, not much used at present, or an electrically heated box with thermostatic temperature control as supplied by Engelhard. The cold junction is frequently buried in the ground at a depth sufficient to insure constant temperature. Any of these systems permit the use of ordinary copper leads from junction box to instrument.

More generally some method of compensating the instrument for cold junction variation is employed. This correction may be applied manually, knowing the cold junction temperature, or it can be made automatically. Several instruments which extend the cold junction to the indicator vary the pointer setting by means of a bimetallic spiral, a system developed originally by Bristol. Wilson-Maeulen places a Wheatstone bridge in one lead of the couple circuit with the resistance of one arm of the bridge located in the cold junction zone. This, in effect constitutes the superposition of a resistance thermometer circuit upon the couple circuit in such a manner that variations of cold junction temperature are automatically added to, or subtracted from, the millivoltmeter reading, due to the couple. As in the case of the resistance thermometer, the bridge requires occasional standardization of the battery voltage.

Styles of Pyrometer Indicators.—Like resistance thermometers, thermocouple pyrometers are adapted to multiple indicating and recording. Similarly, these instruments may be indicating, recording and/or controlling (or signalling). Usually the recorder is of the strip type although a number of makers can furnish disk chart instruments. Time cycle controllers are also available wherein the controlled temperature may be automatically varied with time in any predetermined manner.

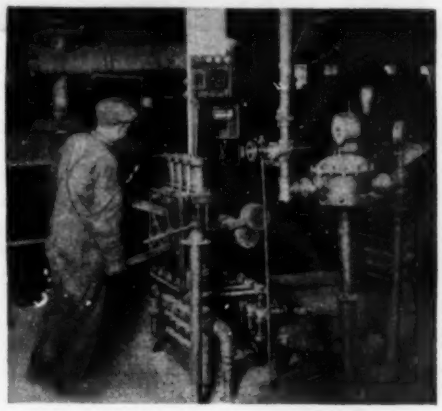
Before passing on to automatic temperature control, one further application of the thermocouple should be noted. This is not, however, a pyrometer as it is not used for temperatures much above 1,000 deg. By placing the hot junction of a couple in some form for contact with a surface, either flat or cylindrical, means are available for determining surface temperature. While not strictly a precision device, this is the most satisfactory, easily used method for measuring the temperature of moving surfaces such as drier rolls.

Automatic Temperature Control

Automatic temperature control always involves three elements—a temperature sensitive device, a controlling system actuated by the sensitive element and a controlled device for regulating the heating or cooling medium.

Controllers usually are actuated by fluid pressure or by electricity. The first type makes use of air, water, steam and vapor tension to control valves, dampers, or electrical contacts. The electrically actuated types regulate motor-operated and solenoid valves and dampers as well as switching or resistance-changing equipment if electrical heating is to be controlled.

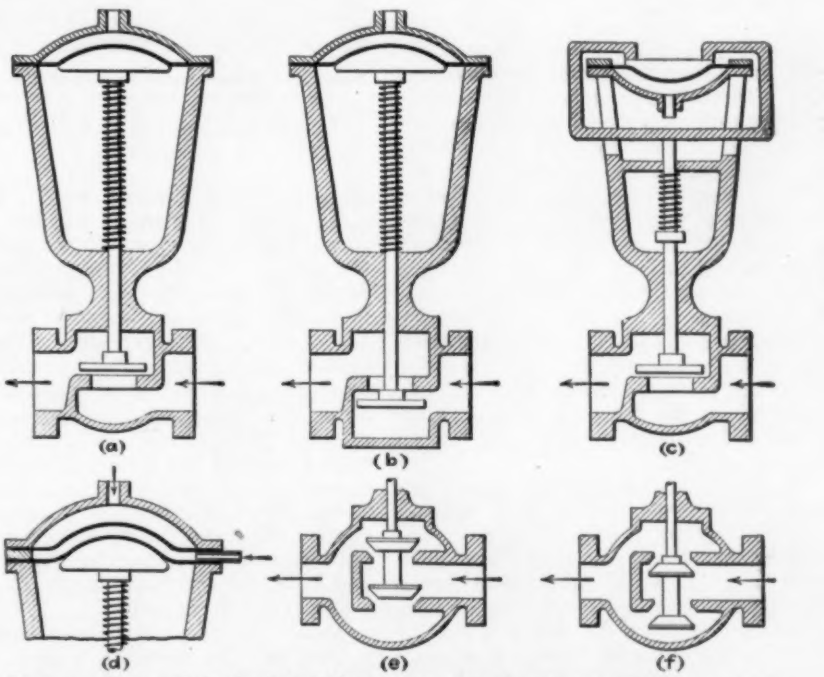
Fluid pressure in the fluid-actuated type may be controlled through pilot valves adjusted by the temperature responsive element; or increase in vapor tension of a liquid in a bulb located in the hot zone may act directly to regulate the controlled valve. This type is used in self-actuated temperature regulators



Signalling Indicating Pyrometer Made by Brown, Used on Water-Gas Set

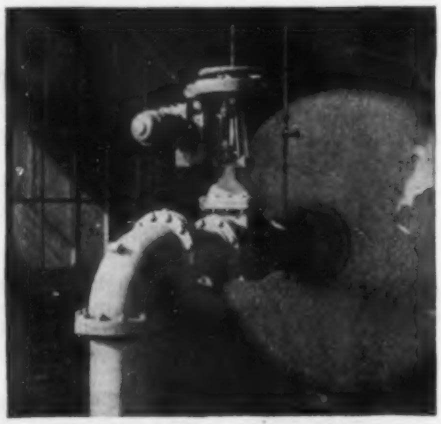
and is not usually considered to be quite as accurate as the pilot valve variety. In either case, however, the fluid pressure is exerted against a flexible element which adjusts a valve or damper or trips an electric contact. Flexible elements ordinarily consist of rubber diaphragms or metal bellows.

Valves and Dampers.—Valves in general are of two kinds—those which



Common Types of Controlled Valve Illustrating Direct and Reverse Action, Disk and Balanced Valves and Various Diaphragms

(a), (c), (e) and (f) are throttling valves, (b) is open-and-shut. Air pressure closes direct valves (a) and (e), and opens reverse valves (b), (c) and (f). Valve (d) has a double diaphragm



Cutler-Hammer Motor-Operated Unit Applied to Valve in Gas Plant

close and those which open with increase in pressure on the diaphragm. Terminology varies regarding these two types, but the most logical seems to be that which calls the first direct acting and the second reverse acting.

Bristol Motor Unit to Operate One or Two Valves

Other variations in controlled valves are illustrated in the drawing on p. 241. If the line pressure is not too great globe valves of the types in (a), (b) and (c) are used. For greater line pressure, balanced valves as in (e) and (f) may be needed. If the valve is one that should open in the event of failure of the controlling pressure, (a) or (e) is used. If it should shut, (b), (c) or (f) is used. Valve action may be either throttling or open-and-shut. In throttling valves, the disk or plunger seeks a position where line pressure drop plus spring pressure balances control pressure and permits continuous flow of heating medium. Such valves appear at (a), (c), (e) and (f). Open-and-shut valves such as (b) are either fully opened or fully closed at all times. They are usually preferred where the temperature lag in the controlled apparatus is slight or the apparatus itself has a high heat-storing capacity. On the other hand, throttling control is desired where the lag is greater and the other valve types shown are consequently applied.

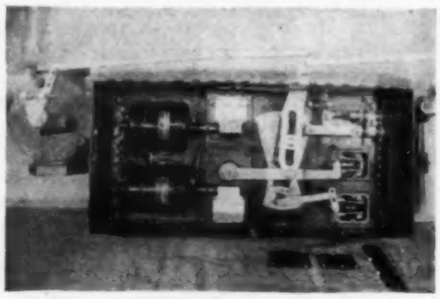
In general, direct-acting valves are used to control heating and reverse-acting, cooling media. However, as will appear later, the controlling pressure may be made to respond either directly or reversely to a rise in temperature and hence the choice of a valve may depend upon whether it is to open or shut upon failure of the control pressure. It should be noted that balanced valves are not usually intended for pressure-tight service.

Sketch (d) shows still another type of diaphragm valve sometimes used. This employs two separate diaphragms so that the valve may be controlled from two sources. For instance, when a cycle controller is used to terminate a heating period, pressure upon the second diaphragm may shut off the steam independently of the temperature control system.

Damper-operating devices are simpler than controlled valves, consisting of a pressure responsive element which actuates a lever to multiply the motion. The damper may be directly connected or moved through rods or cables.

Electrically-Operated Valves.—When the controlling device operates electrically, solenoid valves are often used. Here a globe or needle valve or balanced plunger is normally held open (or shut) by means of a spring. Passage of current through the coil of the solenoid causes the armature to move to the other extreme of its travel so that the valve is then fully closed (or open). The chief advantage of this type is its low cost and simplicity. It is not, however, as reliable as the motor-operated valve. The latter is made in two general classifications, the first embracing open-and-shut valves and the second, more complicated throttling or step-by-step-adjustment valves.

Motor valves of the open-and-shut class are relatively simple affairs, usu-



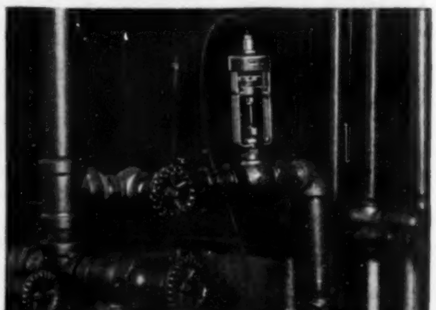
Automatic Temperature Control Company's Three-Position Balancing Controller
This device controls fuel and air supply where there is a considerable lag

ally employing a small motor, geared down either to turn or lift the valve stem. Limit switches stop the motor at the open or closed position and reset the device so that the next impulse will move the valve to the other extreme. Such valves are controlled either by contact-making automatic control equipment or by push button stations. In some, the operating mechanism is an integral part of the valve, while in others, notably the Cutler-Hammer, the operating unit may be attached to any valve. Outside the field of automatic control, these valves provide many opportunities for eliminating hand labor and bring the control of many valves to a single operating point.

Motor valves may be used singly or a pair may be operated from a single mechanism so as to proportion two materials such as gas or oil fuel and combustion air. Both valves may be for high pressure service or one may be a butterfly for low pressure air, as in the Bristol combustion control valves.

Throttling controllers have been responsible for the exercise of much ingenuity. In general, they operate by making a small change in the valve setting in whichever direction is called for by the controller, and making further small corrections thereafter at intervals until the controller again indicates that the control temperature has been reached. The time interval between the additional corrections is usually adjustable, so as to handle various conditions of time lag in the apparatus.

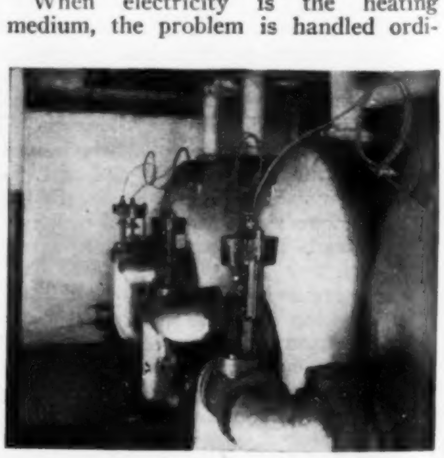
Such valves tend to eliminate hunting



Self-Operated "American" Regulator Controlling Heat in Process Tanks

and to maintain the proper valve opening at all times. To accomplish this where there are fluctuations, the Automatic Temperature Control Company's balancing three-position controller may go one step farther and place a negative adjustment upon the valve as soon as the temperature curve has turned back toward the normal. This prevents overshooting the control temperature. Or the same controller may be adjusted as above to give small increments of regulation if desired. It is to be noted that the need for throttling control is again, as in the case of fluid-operated valves, dependent both upon lag and the heat-storing capacity of the apparatus.

When electricity is the heating medium, the problem is handled ordi-



Self-Operated Fulton Sylphon Regulators Controlling Temperature of Liquid Heaters

narily by means of relays and a magnetic switch. If step-by-step control is required, some method of cutting in or out a greater or lesser number of heating elements is employed.

Temperature Controllers.—Attention has now been directed to two of the three elements entering into temperature control. Temperature sensitive devices and controlled devices have both been examined and it remains to take up the methods used to transmit the orders of the sensitive element to the controlled device. In the case of electrical control systems, this agency consists in nothing more than the connecting wiring and perhaps a relay and need not be considered further. Fluid-actuated controlling devices, however, involve a number of interesting types of which the air-operated is perhaps most common. But since self-operated controllers are the simpler they will be taken up first.

Self-Operated Controllers. — These controllers use a volatile liquid in a thermo-sensitive bulb which is connected directly by flexible tubing to a pressure responsive element adapted to operate a direct-acting or reverse-acting valve. Adjustment of the control temperature is made by regulating the pressure of the spring which opposes the actuating pressure. These controllers are not as easily adjustable as the air-operated type, but are suitable for many purposes. Their low price is an attractive feature. An interesting point in connection with one model of Sylphon controller is that the transmitting system is removable to facilitate installation and repair.

Air-Operated Controllers.—Air-operated controllers make use of a pilot valve, adjusted by the thermo element, so as to regulate the pressure of air upon the diaphragm or bellows of the controlled valve. This pilot valve takes one of two forms shown in the accompanying drawing. Valve (a) is used by the Foxboro Company, while variations of valve (b) appear in most other instruments.

In (a), the expansion element is a helical tube which moves a flapper so as to close or partially close a small nozzle from which air is issuing. This raises

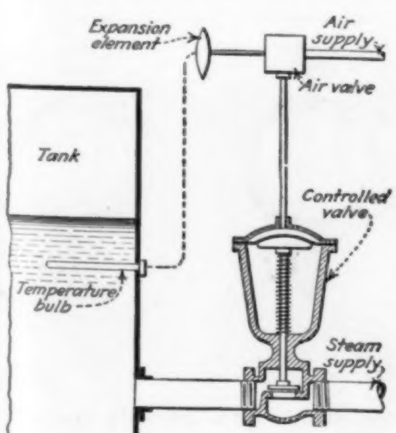
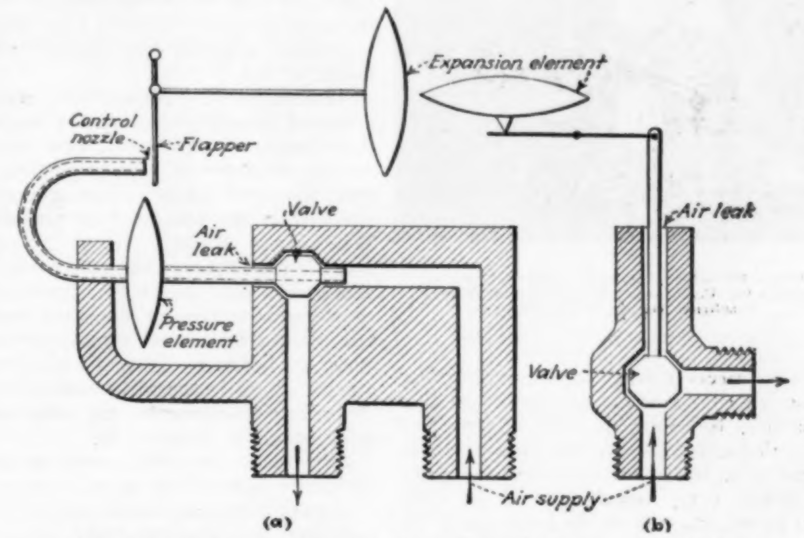


Diagram Illustrating Principle of Fluid-Operated Temperature Controllers

the pressure in the pressure element, causing the latter to expand and close the valve to the right. Two air connections are shown. The inlet connects to the air supply and the outlet to the diaphragm valve. Thus, when the controlled temperature has risen so as to expand the expansion element, the air leak is opened and air is cut off from the diaphragm valve. If the latter is reverse acting, it closes and shuts off the steam. Then, when the flapper uncovers the nozzle with fall in controlled



Diagrammatic Representation of Two Common Types of Air Valve
Valve (a) is reverse and valve (b) is direct-acting

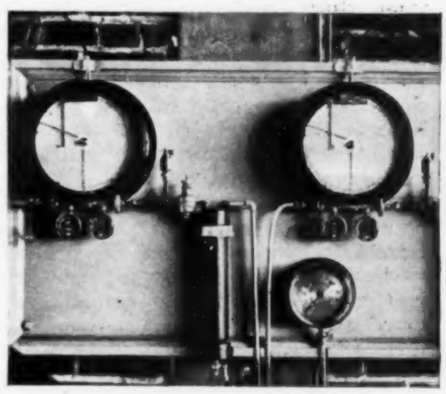
temperature, the opposite movement of the valve takes place, closing the air leak and applying the air pressure. Hence, this air valve is reverse acting.

The type of valve shown in (b) employs the expansion element to control location of the air valve directly. Movement of the expansion element closes the air valve and vents the controlled valve with falling temperature and, conversely, connects the air supply to the controlled diaphragm with rising temperature. There are a number of variations of this principle, as for example, in some instruments, expansion of the capsular element pushes upon the valve stem and opposed needle valves are used. Or as in the Tagliabue instrument, motion of the capsular element is reversed by a lever in locating the air valve as in (b).

The valve shown at (b) should, therefore, be called direct acting. That is, a temperature increase above the control point opens the air valve and admits air to the diaphragm-controlled valve. The opposite effect in either (a) or (b) is obtained by changing the position of the needle valves so that rising temperature affects the diaphragm valve in the reverse manner.

Some variation of the mechanisms shown in (a) and (b) is used in all air-operated temperature controllers. Also, in any system the control point may be adjusted. This is accomplished variously by changing the length of the link between the capsular element and the air valve or by altering the distance between the two. This adjustment is ordinarily made from outside the instrument and covers a considerable temperature range.

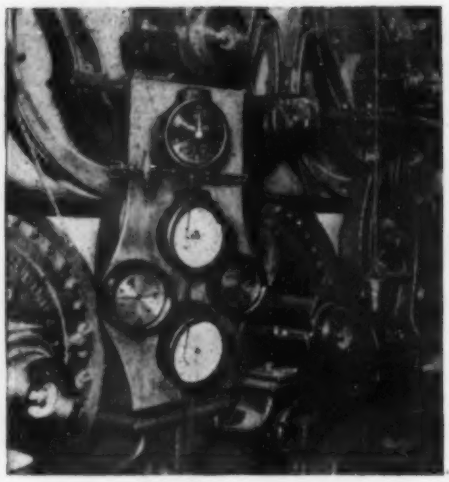
Most air-operated controllers are without the indicating or recording feature. There are, however, indicating and recording controllers available. Temperature responsive systems may be of the mercury, vapor tension or gas-filled types for various conditions. Two air valves may be controlled by a single sensitive element for the control of two heating or cooling media or one of each. This is generally known as the duplex or double-duty system. It may be used, for instance, to heat an apparatus with both high-pressure and exhaust steam, maintaining the control temperature with the former if the supply of the latter becomes insufficient.



Recording Foxboro Temperature Controllers in Wax Sweating House

Or two instruments may be combined in a single case, adapted to control two distinct processes or to control steam supply and condensate discharge. The latter is the more common. The condensate controller is set a few degrees below steam temperature to keep the heating system continuously free of water. This is a compound controller.

Many air-operated controllers are built for mounting directly upon the apparatus controlled, in which case the sensitive element is usually of the bimetallic, differential expansion type. Here a copper rod enclosed in an iron tube, for example, extends into the apparatus. The free end of the rod actu-

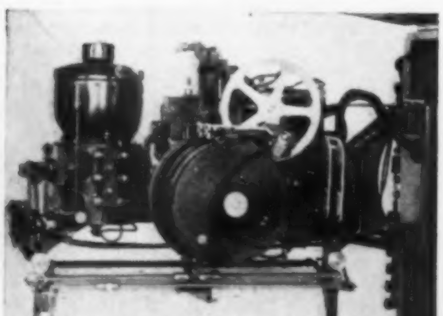


Instrument at the Top is a Duplex Controller Made by Tagliabue, Maintaining Paper Machine Drier Temperature

ates a direct-acting or reverse-acting pilot valve. Some regulators of this type may be operated with water pressure although they are not considered as accurate as the air-actuated mechanisms. In either case, adjustment of the control temperature is made by moving the seat of the air valve.

Steam-Operated Controllers. — Still another fluid-operated controller is the steam-actuated type made by Tagliabue. In this instrument the thermo-sensitive system operates a pilot valve to control pressure of steam, taken from the downstream side of the valve, upon a large diaphragm, integral with the controller. This diaphragm in turn controls the main valve opening, so that, in effect, temperature increase decreases the steam pressure against the diaphragm and closes the valve through spring pressure. The valve is made capable of throttling by applying full line pressure beneath the diaphragm and placing a small leak between the upper and lower diaphragm surfaces.

Any of the regulators which have been described above may be used for throttling service so that the heating-medium valve will float to give substantially constant flow for constant conditions. Air valve (a) accomplishes this by the use of a flapper which first touches the nozzle in a slanting position. Throttling capacity is inherent in the other pilot valves.



Leeds & Northrup Pyrometer Controller of Balanced Potentiometer Type Swung Out of Case to Show Method of Adjustment of Control Point

Contact-Making Controllers. — The majority of electrically-actuated controllers have already been mentioned, but will be summarized here for the sake of completeness. In general, there are two types, thermometric and pyrometric. Contacts may be of the open or sealed-in-vacuo-mercury type. The latter is generally adapted for higher electric loads.

Thermometric controllers may be actuated by expansion type or resistance thermometers. The first case may use any of the types of expansion thermometer discussed above. The second may use either the balanced or unbalanced Wheatstone bridge circuit. Contacts are adjustable for wide or narrow temperature limits and may actuate motor or solenoid valves or dampers, with or without an additional signalling feature such as lighting lights or ringing an alarm. Non-indicating, indicating or recording instruments are available in some or all of these types.

Pyrometer controllers are obtainable generally only in the thermocouple type. The controller may make use of a millivoltmeter or a potentiometer, either null or deflection. The majority of instruments are of the first class while potentiometers appear in the null form in the Leeds & Northrup recording controller and the deflection type in the Wilson-Maeulen. In the millivoltmeter type either indicators or recorders are available. Each must be motor driven, as the action of a chopper bar descending periodically upon the galvanometer pointer is relied upon to make high or low contact if the needle is above or below the control temperature. Generally, the contacts are of the open class, although the Republic instrument employs a mercury switch. Indicating instruments may be had to control one or two equal temperatures and recording instruments from one to six pieces of apparatus at the same temperature. This is accomplished by automatic switching.

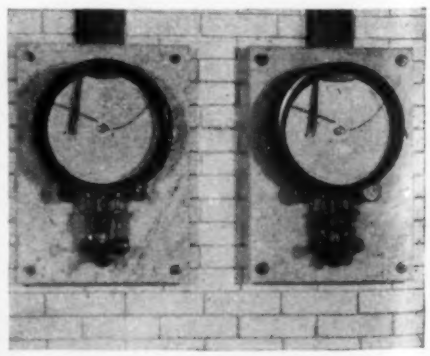
Potentiometer controllers are available in recording and non-recording forms. Of the second, a deflection instrument made by Leeds & Northrup may be used to control up to four independent pieces of apparatus, each of which is automatically switched to the instrument at frequent intervals. One type is for on-and-off regulation, while another is arranged to effect a valve or rheostat change proportional to the instantaneous deviation. A null potentiometer recorder is also made to control one or two pieces of apparatus. In each case the control temperature must be identical in the several furnaces. The Wilson-Maeulin instrument uses an external motor so that several controllers may be mounted on a common shaft to control different temperatures. In this case the action of the chopper bar is similar to that in millivoltmeter controllers in that it causes either the high or low contact to be made, dependent upon whether the galvanometer pointer is above or below the control point. This instrument does not record, but gives temperature indication.

Installation of Seven Brown Indicating Pyrometer Controllers on a Continuous Oven

Humidity Control

Humidity of air is measured directly in industrial practice only in the relatively inaccurate class of instrument which employs some form of fiber, capable of changing in length with changes in humidity, as the actuating element. This type is correctly termed "hygrometer." Psychrometers, comprising a class of instruments capable of considerable accuracy, invariably employ wet and dry bulb thermometers, from the readings of which humidity may be computed. In most cases, the wet bulb consists of some form of thermosensitive bulb encased in a water-saturated wick over which a rapid flow of the air to be measured is induced. This must be worked out carefully or the water may not be at the wet-bulb temperature and large errors may result. The dry bulb measures the actual air temperature adjacent to the wet bulb.

Psychrometers may be indicating, recording or controlling. The hydrodeik and sling psychrometer are examples of the first type. Recorders use circular charts with two pens, one of which records wet-bulb and the other dry-bulb readings. The only precision psychrometer which records directly in terms of relative humidity is an ingenious and recently developed instru-



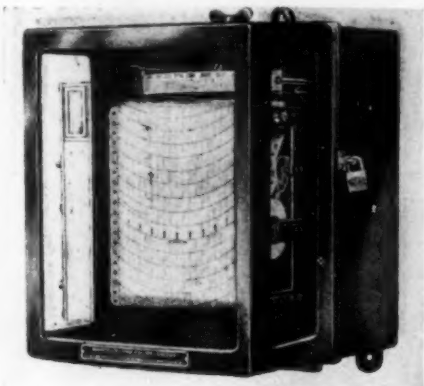
Recording Foxboro Humidity Controllers

ment put out by Leeds & Northrup. This records on a strip chart and makes use of two inter-connected null-type potentiometer circuits, the slide wires of which are adjusted by a single automatic device such as is used in the ordinary null potentiometer recorder. Two resistance thermometers, one in each potentiometer circuit, measure wet- and dry-bulb temperature. The choice of the circuits is such that the balanced condition indicates relative humidity for any dry-bulb temperature.

Controlling psychrometers are compound, air-operated controllers which may or may not include the recording feature. The controller has two temperature-sensitive systems, each of which operates an air valve. One controls dry-bulb temperature and the other the wet-bulb—the latter through control of a steam or water spray. Time cycle control, used for example in dry kilns, may also be included. Here separate cams may control each temperature with time in any desired manner.

Pressure and Service Controls

PRESSURE is measured by liquid columns, as in mercury barometers and manometers, by pressure-sensitive expansion elements and by dead-weight testers. Recording and controlling instruments generally are of the first two types. Liquid columns are used for vacuum, low and differential pressures, while higher pressures, say above 15 lb. (as well as the vacuum and low pressure range) employ expansion elements



Strip Type Pressure Recorder Made by Bristol

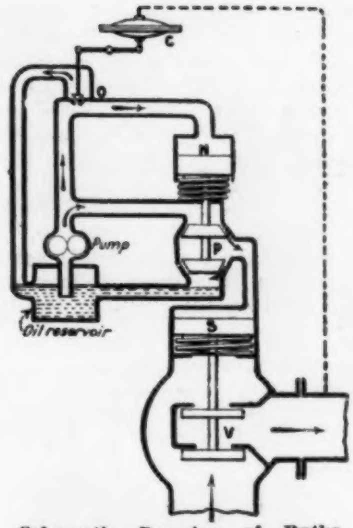
of the diaphragm, capsular, bellows, helical, spiral or bourdon tube types.

Both indicating and recording gages of the expansion-element class are made for single or multiple indication covering the entire range of vacuum and pressure. Some of these indicate temperature or other conditions upon the same dial or chart. Both round and strip type instruments are available.

Liquid column instruments are likewise made in indicating, recording and controlling types. They are used for the measure of pressures below or slightly above atmospheric and find one of their chief applications in connection with the measure and control of fluid flow, to be discussed later. These gages make use of a floating bell or a manometer which may or may not contain a float or some different means other than visual for determining the location of the liquid level. All measure differential pressure, though one pressure may be atmospheric.

Pressure controllers are divided into the simple, self-contained reducing valves or governors and the pilot-controlled regulators used where greater accuracy is needed. In either case, variation of the reduced pressure adjusts the valve setting, but in the latter type, as in the case of fluid-operated temperature controllers, much greater power is available for effecting regulation. Regulators may be used also to maintain the control pressure indirectly as for example in pump governors where the steam pressure to the pump is adjusted by the control pressure. Reducing valves are generally understood and self-actuated pressure controllers are exactly analagous to the corresponding temperature controller and will not be further discussed.

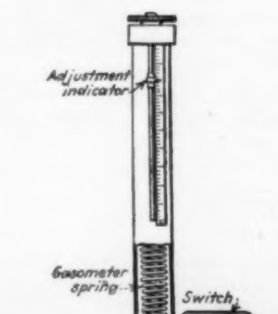
Fluid-operated pressure controllers are generally non-indicating. They are often similar in appearance to the corresponding temperature controlling instruments and similar in construction except that a pressure-responsive element is substituted for the temperature-



Schematic Drawing of Ruths Pressure Regulator

sensitive device of the temperature controller. Obviously there is no pressure controller corresponding to the bimetallic temperature regulator, although a water (or air) operated controller has been developed by Fulton. Like temperature regulators, pressure controllers are also available in the duplex and time cycle types.

An interesting type of pressure controller makes possible the Ruths system of steam storage. An accompanying drawing shows a schematic section of this device. Here oil is used to actuate the setting of the valve. Pressure at



Bell Type Manometer Controlling Electric Contacts Illustrated by Shallcross Instrument

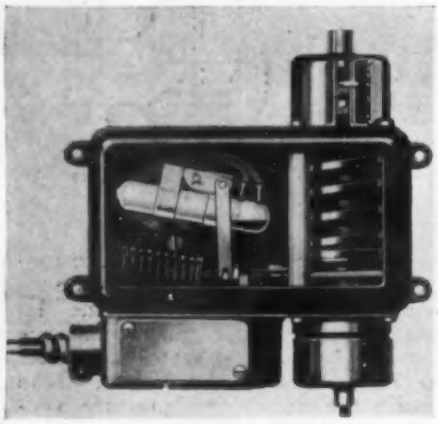
the outlet controls the opening of the orifice O through pressure responsive element C. Thus more or less oil pressure is exerted upon piston N to control the location of pilot valve P. When P opens, oil pressure is exerted upon the servo motor piston S, tending to close valve V. Thus S finds a location where

For Better Exchange of Control Information

A SUGGESTION *has been made to the editors by M. F. Béhar, formerly engaged in instrument manufacture with the C. J. Tagliabue Manufacturing Company, who now proposes a central organization for the standardization of control instrument fittings and the accumulation and dissemination of basic data on control. The proposal is entirely comparable with the similar steps that have been taken in many other fields. Here, almost without exception, the greater facility which has been afforded industry research through co-operative effort and the better understanding which has been fostered between the industry and the users of its products have generously repaid the trouble involved. The editors solicit opinion from readers as to the desirability of such an agency and the form it should take.*

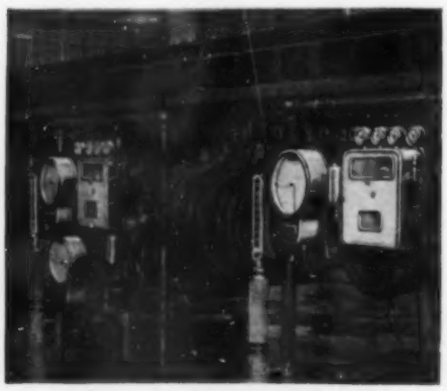
V gives the proper reduced pressure without hunting.

Pressure controllers may also actuate electric contacts. The drawing of the Shallcross pressure switch shows how this is accomplished for very close control of coke oven back pressure. Here a floating bell makes and breaks high or low contacts to set a motor-controlled damper at the proper opening. A simple regulator of considerable accuracy makes use of a metal bellows and Mercoid snap switch. Another control



American Radiator Mercoid Pressure Regulator Uses Metal Bellows and Mercury Snap Switch to Control Motor Valves

made by the Brooke Engineering Company makes use of a diaphragm and a system of multiplication of the diaphragm motion, said to be so sensitive that $\frac{1}{8}$ lb. pressure change will make contact. The instrument is guaranteed not to hunt. It, like the Shallcross, employs a reversing motor for valve or damper control and permits throttling. The Mercoid type is intended for open-and-shut service. None of these instruments, however, is used where there is any great time lag between the valve



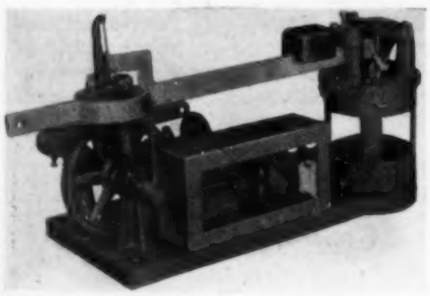
Compound Temperature-Time Controllers Made by Taylor, in Use on Vulcanizers

change and its effect. Special step-by-step regulators, similar to those employed for temperature control, must be used in this case.

Time Cycle Control

Cycle controllers are used to program changes in temperature or pressure with time or to perform other functions such as blowing off an apparatus or signalling at the end of a process. In their simplest form they consist of a clock, a cam and an air valve or switch and are used to bring about some change after a definite period. If a cycle controller is combined with a temperature or pressure regulator, either of the air-operated or contact-making type it becomes possible to follow a predetermined temperature or pressure curve. Such controllers are available in both types for thermometer regulation, and the latter only in pyrometer controllers.

Practically any control feature may be accomplished with equipment of this type. While more complicated situations may require a custom-built job, standard air-operated controllers already available are able to perform such

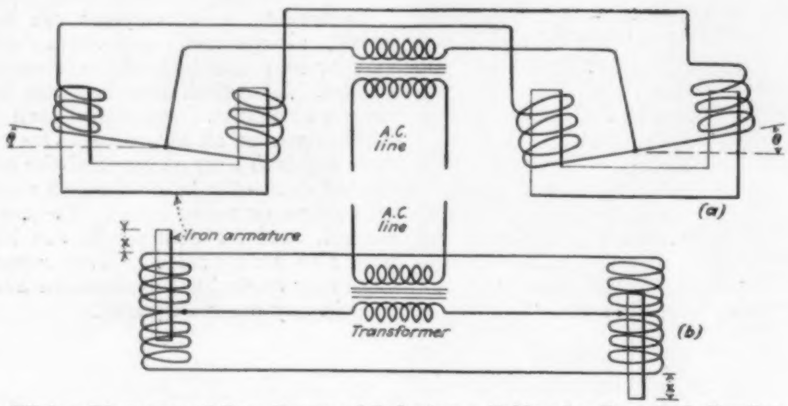


Brooke Pressure Regulator Uses a Diaphragm to Control Motor Contacts

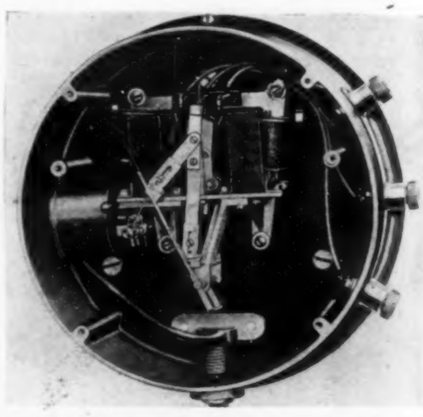
evolutions as follow a temperature curve with two sources of heating or cooling fluid, or one of each; control temperature and remove condensate; terminate the heating process, blow off the apparatus, admit cooling water, drain the water, call the operator and stop the clock, resetting the controls ready for the next cycle. Proper use of cams and air valves makes possible any or all of these operations.

Remote Systems

It is perhaps extraneous to call attention to the fact that control systems which translate indications or orders from the detector mechanism into electrical potential or impulses are inherently capable of remote indicating, recording and controlling. In the case of other systems however, it is impossible or impracticable to transmit indications for more than comparatively short distances. Hence it may be desirable, in the case of temperature, pressure or liquid level, to resort to some system of electrical indication.



Wiring Diagrams of Two Forms of Inductance Bridge for Remote Indication



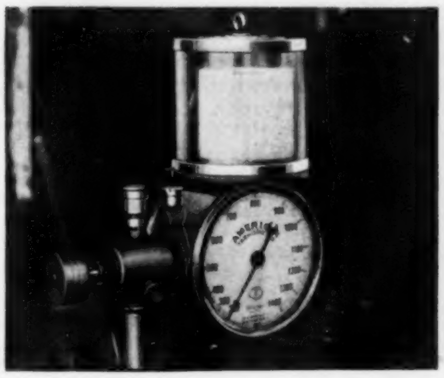
Transmitter of Bristol's Remote Liquid-Level Recorder

In general, the methods used are the impulse-and-ratchet type, the Selsyn synchronous motor and the induction bridge or balance. The first, because of its step-by-step character, is not much used in industrial instruments. The second method is based upon the fact that when two synchronous motors running in parallel have freely rotatable fields connected together, any rotation of the field of the first will be reflected in the second. The third system, developed by Bristol and now also used in a somewhat different form by Brown, is shown diagrammatically herewith. Sketch (a) shows the Bristol system and (b) the Brown. Each consists of two circuits with a common wire, each circuit joined at the ends by impedance coils. Obviously the impedance of any coil may be changed by increasing or decreasing the amount of iron in the core. Hence, when alternating current is passed through the circuits, tilting of the left-hand pair of coils in (a) or moving the plunger in (b) will change the impedance, whereupon the right-hand coils or plunger, as the case may be, will assume the complementary position in order that the impedance of the

two circuits remain equal. One pair of coils in either (a) or (b) may then have the impedances adjusted by a temperature, pressure or liquid-level indication while the other, even though several miles distant, will reflect the position of the first on an indicator, recorder or controller.

Speed Control

Several useful methods have been applied to the measuring of speed of rotation. These include pneumatic, stroboscopic, chronometric, electrical and centrifugal tachometers. The first is now considered obsolete for industrial use. The second and third are not very frequently used industrially at present. Electrical instruments employ a magneto or generator driven from the machine whose speed is to be measured, connected by wiring to an indicator or recorder for determining the speed in terms of the voltage generated. Centrifugal instruments make use of a mechanism similar to the fly-ball governor, or a cup of mercury containing a center well in which a float is placed. Brown has recently developed the latter type for use with the induction balance system of remote indication transmission.

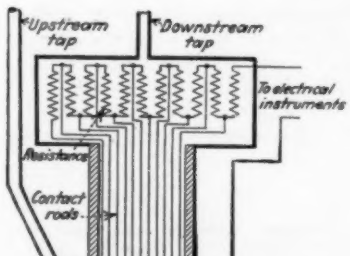


"American" Tachometer With Indicating Dial and Recording Chart

Tachometers are to be obtained in indicating and recording types, the latter in drum, disk and strip chart forms. Multiple record instruments are also available. Contacts may be added for speed control. Control may be effected through changing engine or motor speed or adjustment of a variable speed transmission. Controllers for regulating variable speed transmissions, using pressure, speed or other requirements as the control factor are now made.

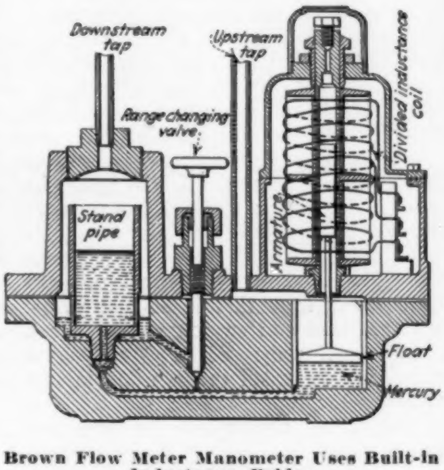
Flow and Level Control

THERE has been a large number of methods developed for measuring the flow of gases and liquids. However, they resolve themselves into methods based upon positive displacement, differential pressure, weirs, turbine wheels and the Thomas electrical system. The first is represented in the ordinary gas and water meters supplied to customers by the public utilities. It also includes certain types of positive displacement pump which may propel as well as



Republic Manometer Uses Mercury as the Liquid and Cuts Out Resistance to Give Indication

meter the fluid or may themselves be propelled by the fluid. For example, small gear and piston pumps are used to meter the various spinning solutions used to making the several kinds of rayon in addition to forcing the solution



Brown Flow Meter Manometer Uses Built-in Inductance Bridge

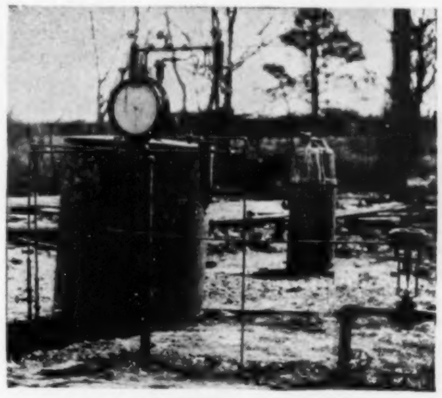
through the spinnerettes into the bath.

On the other hand, double-impeller blowers of the Roots and Connersville type are used as meters and rotate under pressure of the gas being metered. In this case an integrator may show the volume of gas which has passed, which volume may then be corrected to standard conditions of temperature and pressure. To assist this operation, such meters may be provided with a recorder for gas pressure, rate of flow, increments of volume and temperature. As the chart is driven from the meter shaft, a planimeter average of temperature and pressure is accurate.

Two positive displacement meters may be geared together and used for proportioning. If a variable speed drive is used for the connection between the meters, any ratio of the two metered materials may be obtained.

Differential Pressure Meters.—These instruments all consist of some form of orifice (or occasionally a Pitot tube) coupled with a differential pressure indicator for showing the pressure drop across the orifice. The Pitot tube is relatively inaccurate but is sometimes all that can be used. Float meters, such as the Rotameter or St. John, balance a float in a tube of varying cross-section or a float of varying cross-section in a constant orifice. The former is suitable for liquids, the latter for gases. The vast majority of meters of this classification, however, make use of a Venturi tube or an orifice, usually in thin plate. For measuring the differential pressure that results many devices are available, all, however, using a liquid column either with a floating bell or in a Umanometer.

The simplest manometer is a glass U



Recording Flow Controller Made by Foxboro, Regulating Flow of Crude to Tube Still

tube containing a liquid of suitable specific gravity. When the instrument is to be used for recording or controlling, the manometer is of metal and the liquid is ordinarily mercury. The instruments use only circular charts. In the Brown flow meter the inductance bridge is employed together with a range-changing valve that may be used to decrease the head of mercury. The electrical transmitting feature permits remote recording. This instrument may also have an integrator which totalizes on a dial, at the same time marking volume units on the chart. The remote system is likewise used for indicating instruments.

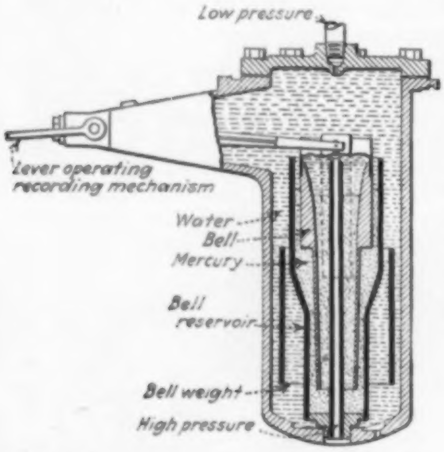
Another remote indicating system appears in the Republic meter, shown in an accompanying sketch. Here rising mercury in one leg of the manometer successively makes contact with a large number of metal rods, acting to cut out resistance coils. These rods follow the law of squares in their vertical location and give equal flow increments for equal resistance changes, thus making chart divisions equal. The recorder mechanism has only to measure resistance change.

The Foxboro type employs a float and direct mechanical operation of the recorder. The harmonic effect of linking

the pen to the float by means of a crank is eliminated through use of a chain and segment linkage. This instrument may be provided with an air valve to control flow, either through setting the supply valve or controlling the supply pump.

Bell-Type Meters.—Among the bell type of liquid column gage, there are instruments employing oil or water for very low differentials and others using mercury for higher ranges. The Bacharach recorder uses the water column and records upon a drum chart. For higher pressures, to 15 lb., this company employs an ingenious mercury seal for the pen rod, retaining, however, water as the operating liquid. An integrator may be supplied. For measuring very low differentials on gas flow there are several bell-type gages available using very large diameter bells. Here again the Brown instrument uses the inductance bridge. A bell-type instrument using oil as the liquid and making electric contacts for control purposes is a non-indicating machine of Brooke design. The control is exercised through a very highly magnifying lever

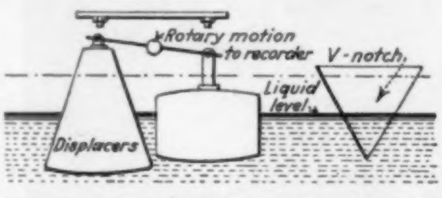
Bacharach Differential Pressure Recorder for Low Pressure Gases



Bailey Orifice Meter Employs Bell of Varying Cross Section to Attain Straight-Line Flow Characteristics

system and is said to be exceedingly accurate. A considerable number of these controllers are being used to regulate the flow of ammonia and oxygen in the pressure system of synthetic nitric acid production. A scale beam forming part of the lever system is calibrated in terms of pressure differential and facilitates adjustment.

The fact that the pressure differential across orifices varies as the square of the flow is responsible for a cleverly designed bell in the Bailey meter. Its cross-sectional area at different heights is such that its motion varies directly, not as the differential pressure, but as the flow. This system greatly simplifies



Diagrammatic Illustration of Displacers in Bailey Weir Meter

the addition of the integrator used with the recorder and permits equal scale division without the use of a cam. A large-bell instrument made by the same manufacturer for small pressure differentials employs a displacer of variable cross-section partly submerged in a mercury well to accomplish the same result.

Weir meters employ a float to measure the head of liquid flowing through a V notch. Here the flow varies as the 5/2 power of the head. The Cochrane meter uses a special type of cam to transform the float motion to straight-line characteristics. Bailey uses instead of a float two displacers of peculiar shape, suspended from a pivoted arm. The relation of the displacement of these bodies at different depths causes the tilting of the arm to assume the straight-line form. Each of these instruments both records and integrates.

Thomas Meters.—A gas meter, entirely different from any hitherto described, is the Thomas electric meter. This depends for its accuracy upon the fact that the specific heat of city gas is substantially constant, regardless of composition. Hence, if the gas be heated to maintain a fixed temperature rise, the energy consumed in the heating is a measure of the weight of gas flow. An accompanying hook-up diagram shows how this is accomplished. Two resistance thermometers, placed in adjacent arms of a Wheatstone bridge, are adjusted to give a balanced galvanometer when their temperature difference, as determined by the gas passing them, is 2 deg. F. The current through the heating coil is then adjusted so that some standard flow of gas will be raised just 2 deg. in temperature. If the flow changes, more or less heat will be required to balance the galvanometer, whereupon a Leeds & Northrup balancing device adjusts the heating circuit resistance to the correct amount. An integrating wattmeter is calibrated to record in terms of gas flow. The machine may easily be arranged to control flow if desired.

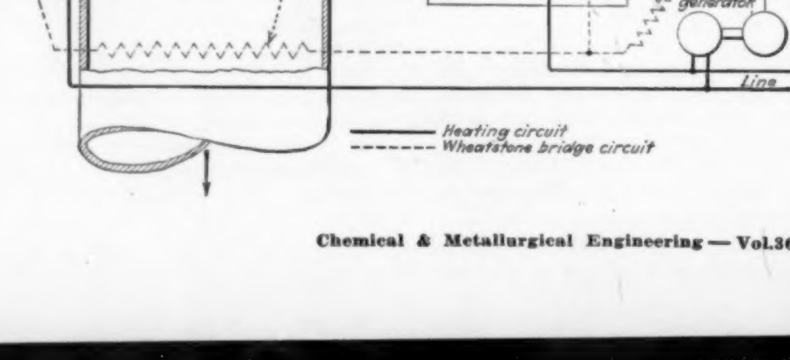
Turbine meters complete the list and are exemplified in the anemometer, a sometimes necessary though inaccurate device for flow determination; and in a much more accurate instrument, the shunt meter recently developed by the Builders Iron Foundry to measure gas and steam flow. This meter shunts a part of the flow around an orifice and through a small turbine wheel which operates an integrator through a magnetic drive.

Level Control

Instruments for this service make use of float or hydrostatic pressure measurement. The Liquidometer is a device of the first class which uses a balanced hydraulic transmission to indicate the position, of the float at a considerable distance on either an indicating or recording gage. Operation of this instrument is independent of the pressure in the system measured as is a liquid level controller using a gage glass for indication, made by Tagliabue. Here the position of the float adjusts a pilot air valve so as to control a pump or supply valve to maintain the control level. Other float level recorders generally use a float connected directly to the instrument by a chain or cable.

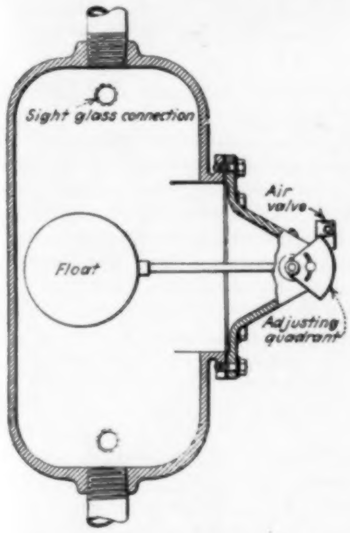
Hydrostatic pressure gages for level indication, on the other hand, ordinarily assume constant pressure above the liquid unless a differential gage for measuring the difference between the total static pressure and the container pressure is used. Of the former class are the instruments consisting of a sensitive expansion type pressure gage connected to an air bell or diaphragm chamber placed at the bottom of the liquid container. The gage may however be a manometer with one leg open

Circuits of Thomas Electric Gas Meter Indicating How Temperature Rise of Gas is Maintained Constant



to the atmosphere. But if the normally open leg be connected back to the top of the tank, as in the case of the K. S. Telegage, the indicator becomes a differential gage and is independent of container pressure. This system is likewise employed in other cases, using a manometer-type recorder.

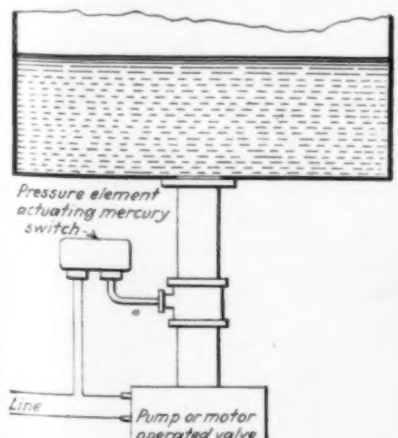
When an air bell is the detecting device, it becomes necessary to supply a small pump in the connecting line to make sure that the pressure system is full of air at all times. An occasional few strokes of the pump suffices. Use of a diaphragm box prevents air loss and is consequently of frequent applica-



Float Type Level Controller Made by Tagliabue

tions. Both types of instruments may be used for remote indicating up to about 1,000 ft. They may also actuate a pilot valve or contacts for level control.

Where more distant indication than



Mercoid Level Controller Actuated by Direct Static Pressure

1,000 ft. is required, remote electric indicating devices such as the induction balance circuit are employed. The Republic system, employing changes in mercury level in a manometer to cut out resistance, is also available.

Where level changes only are to be measured, or where correction can readily be made for the height of the container above the instrument, the air systems may be dispensed with and actual hydrostatic pressure measured on a pressure gage or pressure balance of the weighing-scale type. A simple control of the static pressure type employs a pressure responsive element to actuate a mercury snap switch for valve control.

Recorders for liquid level are obtainable in both strip and disk chart forms, for single or multi-pen recording. Contacts are supplied for signalling high and low water levels.

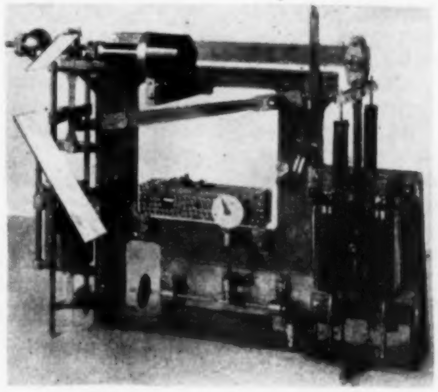
Control Based Upon Properties of Matter

THIS section concerns control systems for gas analysis, weight, specific gravity, density, viscosity, calorific power, electrical conductivity and hydrogen-ion concentration.

Gas Analysis

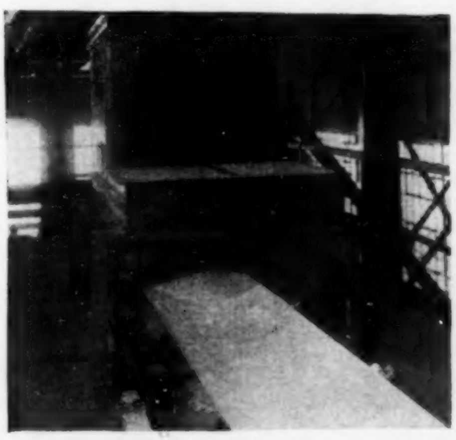
Gases may be analyzed automatically by chemical, mechanical or thermal conductivity means. The first ordinarily makes use of an automatic Orsat apparatus and finds wide application in the boiler house for CO_2 determination. The second employs direct weighing or a density balance and the third compares the thermal conductivity of a sample of gas with a standard. This last method, made possible largely through the pioneering of E. R. Weaver of the U. S. Bureau of Standards, is now attracting much attention, not only as a CO_2 meter, but as an electrical chemist in plants where continuous analysis of various gas mixtures is desirable. The system has the advantage of easy adaptability to automatic control.

Several manufacturers are now in a position to supply apparatus for the determination of one or several gases by this method. Briefly, the apparatus consists either of a null or unbalanced type Wheatstone bridge circuit, in two arms of which are placed identical resistance thermometers capable of being heated by the bridge current. One is sealed in an atmosphere of the standard gas and the other in the gas to be measured. If the gases are identical, temperature drop in the thermometer



Mechanism Used by Chatillon in the "Telepoise" Scale for Indicating and Actuating Weight Integrator

coils due to conduction through the gases will be identical and the resistances equal. Variation in the sample gas will affect the rate of heat loss from the coil and hence its resistance, resulting in an unbalance of the bridge which can be measured in terms of gas composition. These instruments are available in both indicating and recording forms. For further information as to the theory and application of thermal conductivity analysis, the reader is referred to Mr. Schmid's article earlier in this issue.



Merrick Conveyor Scale Integrates Continuous Load on Belt

Weight Measurement

Automatic scales may be classed as those that weigh stationary, semi-moving (or intermittent) and moving loads. The first classification includes weigh tanks and hoppers in which a container is balanced by a scale mechanism set to trip a valve or gate when a predetermined load has entered the container. Other weighing mechanisms such as the Merrick may be used automatically to balance any load placed on a platform scale. The Merrick mechanism makes use of a power-applying system to move the beam rider in the proper direction whenever the beam is out of balance. The system may operate a weight integrator or it may print and deliver a weight ticket.

The scale tank principle may be used for the intermittent measure of a practically continuous liquid flow by use of two or more tanks whose scale mechanisms operate to close a feed and

Schaffer Poidometer Maintains Uniform Feed Rate of Bauxite in an Alum Plant

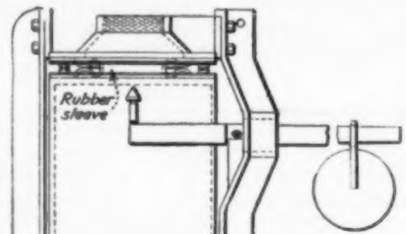
open a discharge valve at the proper load. The Richardson "Conveyoweigh" is also a semi-continuous device, employing two belt conveyors in series, one of which operates intermittently to feed the second, a continuous conveyor. The second is mounted on a scale suspension and is connected to a scale balance which operates mercury switches. When the predetermined weight has been indicated by the weigh conveyor, the feeder stops until part of the weighed load has been discharged. Thus, the scale may operate as a practically continuous feeder or proportioner.

Continuous weighers may integrate a continuous load and they may also control and maintain the load constant. The new Chatillon Telepoise is of the first class. Here a conveyor belt passes over a scale-balanced set of belt carriers. Position of the scale beam is ingeniously converted into electric impulses which vary in number per unit of time, directly as the instantaneous load and so may operate an integrator. An example of the second class is shown in the Schaffer Poidometer which controls the flow of solids to a conveyor belt which passes over a weighing section so as to maintain a constant feed per unit of time. The scale is hence used as a feeder, or as a proportioner if two or more scales are used.

Specific Gravity, Density and Viscosity Control

Specific gravity is measured by comparing the weight of a unit volume of material with a standard. Water is used as the standard for liquids and solids, and air for gases. The effect may be obtained indirectly, and is, for liquids, by use of the Westphal balance or the hydrometer, or a variation of one or the other of these. The Bailey recorder system makes use of a modified Westphal balance in which a displacer of relatively large volume is hung from one end of a balance beam and balanced by weights of relatively small volume. When this system is immersed in liquid it will seek a balance point determined by the specific gravity of the liquid and the relative weights and displacements of the bodies hung from the balance. Movement of the beam with change in specific gravity can hence be recorded on a circular chart in terms of specific gravity. Bailey uses a magnetic transmission to connect the balance and recorder systems, eliminating packing difficulties. Temperature variation is compensated by using as displacers thin-walled, expansible containers filled with the type of liquid under test. Where liquids are being mixed to a certain gravity, the use of contacts or an air valve on the recorder can be made to control the supply of one liquid and hence the gravity. As the composition of a solution is frequently reflected in its gravity, the system functions also to control composition.

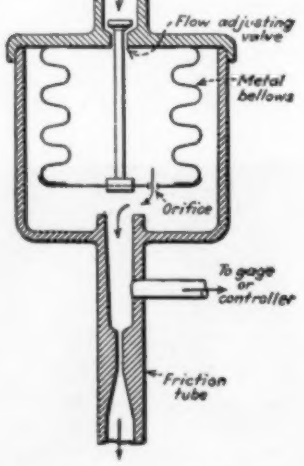
The Lux instrument for recording city gas specific gravity passes the gas over a balanceo piston, the position of which is recorded on a chart. Here, in



Bradley Valve Made by Thyle Maintains Constant Density of Thickener Discharge

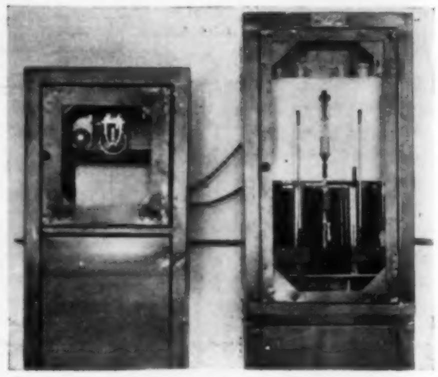
effect, the passing gas is weighed in comparison with air. The Ranarex system, on the other hand, compares the viscosity of the gas under test with a standard. Comparison of the torque required to rotate paddles in chambers containing each gas gives a measure of the specific gravity.

Density Control.—In thickening pulps in a continuous thickener, or in feeding



Automatic Viscosity Meter Proposed by C. M. Larson

stock to a paper machine, it is desirable to maintain a constant density, in the one case at the thickener discharge, and in the other of the fourdrinier feed.



Burgess-Parr Company Recording Calorimeter Measures Heating Valve of Gas Continuously

Apparatus is obtainable for both purposes and functions by weighing a known volume automatically and governing a valve accordingly. An underflow control for thickeners is illustrated herewith. Increased weight of the contents of the controller, corresponding to increased density, tends to open the valve and increase the discharge. Decreased density operates conversely.

Viscosity Control. — Viscosity controllers are a recent development. A type now commercially available and supplied by Thyle makes use of the friction of fluid films to measure and control viscosity continuously. A cylinder rotates within the fluid, driven by a motor which is free to turn on an axis about its own shaft. Increase in viscosity results in greater torque required to turn the cylinder and hence tends to rotate the motor. The motor however is counterbalanced so that its position is a measure of viscosity which can be used to operate controls. Another system proposed by C. M. Larson at the December, 1928, meeting of the American Petroleum Institute, illustrated herewith, makes use of a constant flow controller of the self-actuating type, feeding a friction tube. Pressure between the two is a measure of absolute viscosity and can be adapted to operate indicators, recorders or controllers.

Calorific Power, Conductivity and pH Control

Two instruments on the market are capable of measuring and recording the calorific power of gas continuously and automatically. Each is similar in that a measured volume of gas is burned and its heat transferred to another medium, the rise in temperature of which depends upon the calorific power of the gas. They differ, however, in the method of carrying this out. The Burgess-Parr Company instrument uses a measured volume of water as the heat absorbing medium and the Cutler-Hammer Thomas calorimeter, air. Reference to the schematic drawing of the Thomas system, bearing this distinction in mind, will illustrate the principle of each. A metering system supplies constant proportions of gas, combustion air and heat absorbing air (or water) to the combustion chamber and absorber respectively.

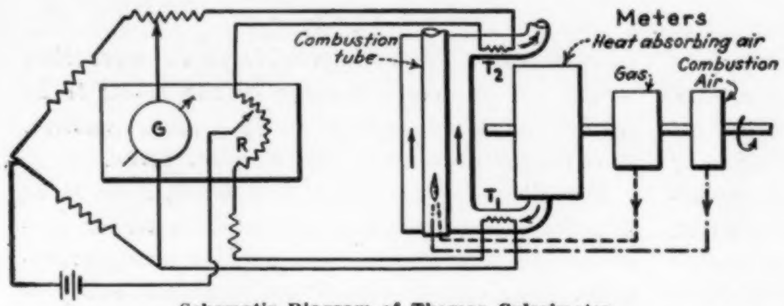
Resistance thermometers T_1 and T_2 placed in adjacent arms of a self-balancing Wheatstone bridge circuit measure the temperature rise of the absorbing medium. The bridge-balancing mechanism actuates the pen of a strip-chart recorder, recording in terms of calorific value of the gas.

If contacts are used with the recorder, butterfly valves may be controlled to regulate the mixing of two gases. Cutler-Hammer employs this system where the quality of the two gases remains fairly constant. For fluctuating supplies, an additional simplified quick-acting calorimeter is used to regulate the valves.

Conductivity Control. — Where conductivity can be used as a measure of composition, as for example in an acid bath, comparison of the electrical conductivity of the bath with a standard furnishes a convenient method of indicating, recording or controlling the composition. Leeds & Northrup uses this method for determining ash in sugar and salts in boiler water as well as for controlling bath composition. The latter apparatus is shown in the accompanying drawing. It consists of a self-balancing Wheatstone bridge with conductivity cells as the resistances of two adjacent arms. Both cells are immersed in the bath, but one is sealed and contains as a standard a solution of the desired composition. This is placed in the bath to eliminate the effects of bath temperature variation. The balancing mechanism makes high or low contacts if the bath composition changes, thereby setting a supply valve by means of a reversing motor.

Control of pH.—Control of hydrogen-ion concentration is now effectively practiced in many industries. In the majority of cases this is accomplished manually through the assistance of indicating methods which may be colorimetric or electrical. The latter is the fundamental method but is less frequently employed industrially than the former. Colorimetry involves the use of indicators which assume a definite color at a particular pH value. Color standards are supplied, covering the entire pH range in small steps, with which the solution containing the appropriate indicator is compared. In the LaMotte system, liquid indicators and liquid standards in ampoules are employed. The Wulff system uses sensitized indicator papers for a somewhat smaller range, together with colored glass standards.

The electrical method employs an indicating or recording acidity meter (null potentiometer) in connection with the appropriate cell in contact with the sample. The recorder may be adapted for automatic control.



Schematic Diagram of Thomas Calorimeter
Resistant thermometers T_1 and T_2 measured temperature rise of heat-absorbing air to give indication of calorific power of gas

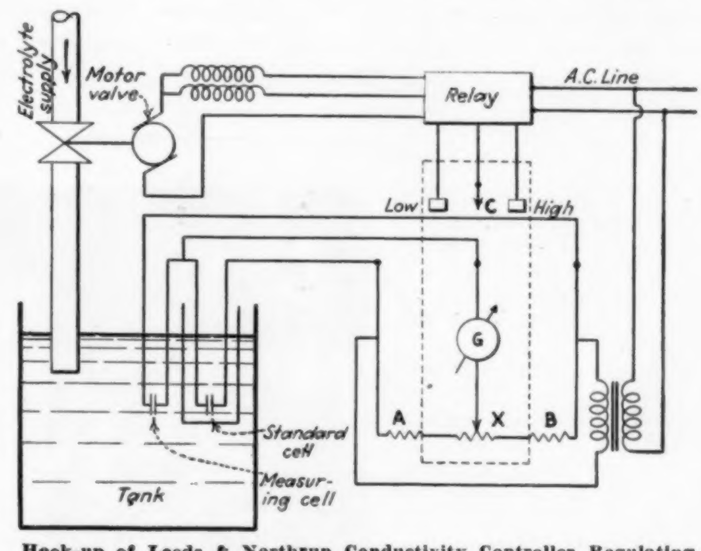
Other Control Applications

There are many other interesting applications of automatic control which are beyond the scope of the present article and yet should be mentioned. Among these is combustion control which is used to regulate fuel and air supply to meet existing demand and (or) to give constant flue gas composition. This can be, and is sometimes, made fully automatic.

Combustion control is of particular interest in connection with the generation of process steam. Methods are available for controlling boiler output on the basis of steam demand, but when this demand is likely to vary suddenly and to a considerable extent, the control system is usually assisted by means of a steam accumulator. For further information the reader is referred to the September, 1927, issue of *Chem. & Met.* where steam accumulation, the balancing of process steam and power and the control of combustion are discussed in some detail.

In the electrical field, power factor correction is applied by means of capacitors, synchronous motors and synchronous condensers. Methods have been worked out using power-factor meters as controllers for continuously applying the desired correction through these agencies. Power demand may also be regulated. This is done through the cutting off of part of the load automatically if the demand should increase beyond a desired peak. For instance, in the system developed by E. T. Moore, the power load is regulated in pulp mills by disconnecting one or more grinders from the line so as to maintain the total load within the limit desired. A time-delay feature is incorporated into the system so that sudden increases in demand, above the limit, if they are of short duration, will not cause the limiting feature to operate. However, if the increased demand should continue, grinders are automatically cut out, one at a time, until the total load has receded within the allowable limit.

Again, for other chemical engineering uses, electrical instruments have interesting applications. Ammeters, for example, are used in controlling operation of beaters in the paper mill. Adjustment of blade clearance is made as the beating progresses in accordance with the ammeter reading. This has not, to our knowledge, been done automatically, but could be done if it should prove an economic advantage. Control of the jordan is similarly carried out.



Hook-up of Leeds & Northrup Conductivity Controller Regulating Acid Bath Concentration

The three-electrode vacuum tube is being used with increasing frequency for control purposes in chemical engineering plants. It is being used for gas analysis, for the measurement of pressure, thickness and moisture. Machines are commercially available for the control of thickness of sheet goods such as rubber and oil cloth. The vacuum tube is also used to control the moisture content of paper in the paper machine drier. These applications represent only a fraction of those which have already been explored, and doubtless many others will be discovered.

The Unit Processes and

AUTOMATIC CONTROL

JUST AS CONTINUOUS PROCESSING *is everywhere replacing batch handling as soon as it can be applied profitably, automatic control is taking the place of manual operation as rapidly as it proves itself to be an economical and reliable method of cutting production costs and improving the quality of the product. Automatic control is not alone a tool for use in continuous processing, however, since it is as useful for maintaining conditions constant—or varying them in some predetermined manner—in a batch kettle or vulcanizer as it is for holding exactly the correct flow and temperature conditions in a pipe still.*

Consideration of some of the things that have been and can be done in automatic control, from the standpoint of the unit processes of chemical engineering, is a convenient way in which to bring the subjects covered in the previous section down to concrete cases. It is impossible to do more than scratch the surface but many of the points to be touched upon will very probably prove suggestive. It is in this expectation that they are given.

Not all unit processes, at first blush, seem to be fit subjects for automatic control. Sometimes conditions are such that they are not, but nearly everywhere temperature control plays some part and possibly pressure or flow control as well. The chemical unit processes, involving always as they do some of the mechanical or physical processes, will not be differentiated but it should be borne in mind that such operations as amination, nitration and sulphonation present many opportunities for the saving of an occasional batch, the shaving of a few cents or the improving and stabilization of quality through suitable instrumentation.

FOR MOST of the information contained below, the editors are indebted both to the manufacturers of control equipment and to equipment users as well. They take this opportunity to thank all those whose assistance has made this discussion possible.

Heat Technology. — Heat technology is an integral part of nearly every unit process. It involves all those applications of heat and cold upon which chemical industry is so universally dependent. In practically no case are indicating and recording instruments unwarranted, and more frequently than not, automatic control equipment as well will more than pay its way. There are many cases on record in which such apparatus has returned its cost in a remarkably short time, sometimes through the saving of a single batch and often within the space of a few months.

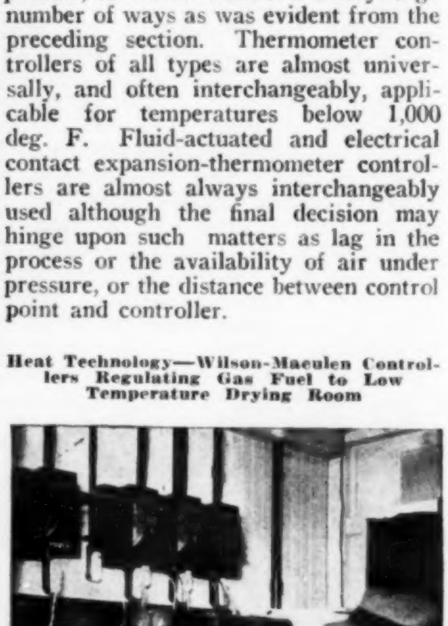
Automatic temperature control frequently enters into such unit processes as separations of various kinds, leaching and dissolving and occasionally into dust and fume handling. It represents about the only type of automatic control that is applicable in these cases although they will sometimes be found cropping out in connection with other unit processes. Among the others, heat application is so general that it will be discussed under the various unit processes themselves.

Heating or cooling, as a separate process, can be controlled in a very large number of ways as was evident from the preceding section. Thermometer controllers of all types are almost universally, and often interchangeably, applicable for temperatures below 1,000 deg. F. Fluid-actuated and electrical contact expansion-thermometer controllers are almost always interchangeably used although the final decision may hinge upon such matters as lag in the process or the availability of air under pressure, or the distance between control point and controller.

Heat Technology—Controlling Time, Temperature and Condensation in a Horizontal Vulcanizer with a "Tag" Instrument

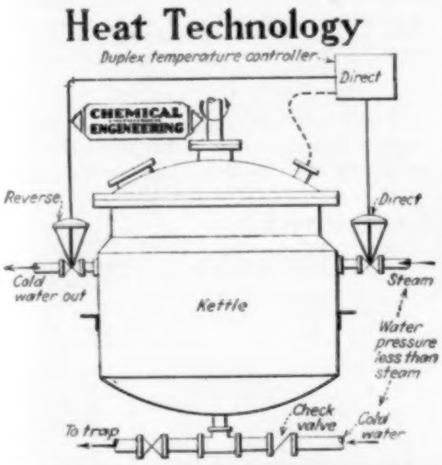
Heat Technology—Taylor Instruments Regulating Steam and Cold Water Supplied to Calender Rolls

Heat Technology—Wilson-Maeulen Controllers Regulating Gas Fuel to Low Temperature Drying Room



In the high temperature field, automatic control instruments are very nearly limited to those that use a thermocouple. Here, the controlling forces are electrical and the choice usually is determined by the accuracy required or by the range. Again the question of lag will be a determining factor, not so much in the controller as in the controlling valve, damper or switch.

Time cycle control of temperature is often advantageously used. An accompanying drawing suggests how this has been applied in a vulcanizer. The controller cam has been cut so that the temperature is varied at intervals as required, and when the cure has ended the cam causes the steam to be shut off and the blow-off and cold water valves to be opened. Thus, the process is not only terminated but overcuring through

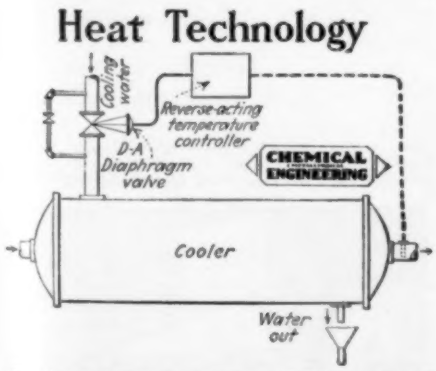


Exothermic Processes May Require Cooling Water After an Initial Heating Period

Here, steam pressure serves to exclude the cooling water until the temperature becomes high enough to shut off the steam and open the water outlet

heat stored in the apparatus is prevented by means of rapid cooling.

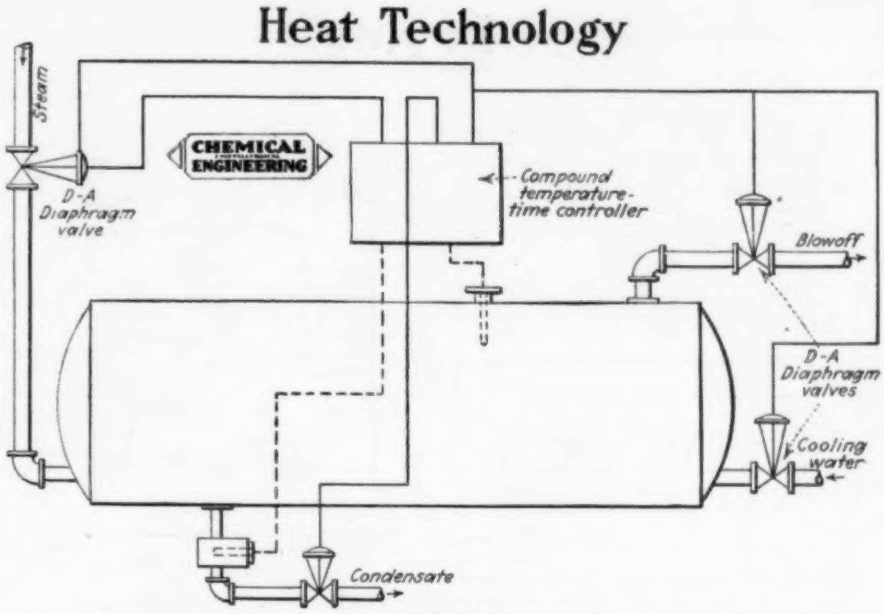
It is fairly obvious that cycle control has wide applicability in batch processes of all kinds either where temperature is to be varied or where the process is



Cooling Requires Control Which is the Reverse of that Used in Heating

Either the diaphragm valve or the air valve in the controller may be reverse and the other direct-acting.

simply to be ended after a definite period. Although cycle control has no place in continuous processing where constant conditions maintain at every point indefinitely, other types of temper-

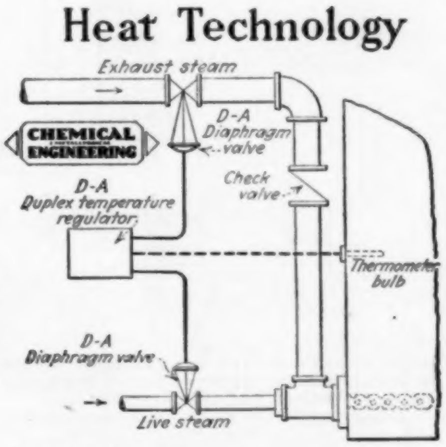


One Type of Installation for Control of Time, Temperature and Condensation in a Vulcanizer

Temperature follows a predetermined curve until the cure is ended when the steam is shut off and the blow-off and cold water inlet valves are opened

ature control are not so limited. The drawings will suggest a number of applications that have been used for both intermittent and continuous operation.

Drying.—Drying is carried out either at atmospheric or at reduced pressures. Control of pressure, however, is ordinarily handled through temperature of



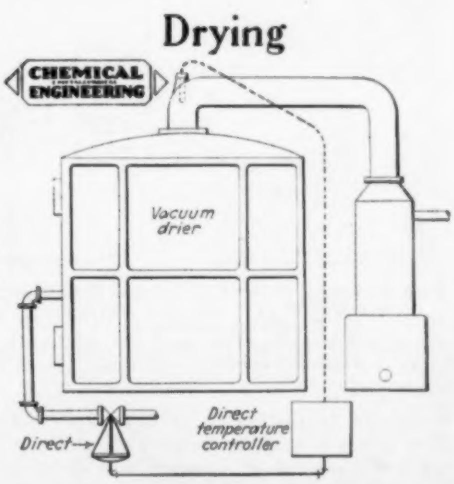
One Way to Control two Sources of Heat to a Single Apparatus by Use of a Duplex Temperature Controller

Direct-acting diaphragm valves and a direct-acting controller serve to make up any deficiency of exhaust with live steam if the supply of the former should be insufficient.

the condenser and hence does not involve pressure control except insofar as the vacuum pump assists in maintaining the proper vacuum. Consequently, temperature control or control of humidity through wet - and dry-bulb temperature, furnishes the principal field for instrumentation in drying.

The simpler temperature controllers are usually sufficient for ordinary drying. The operation may of course be at high temperature when some form of pyrometer controller must be used, but the great majority of drying installations use thermometer controllers to control either one or two heating media or a heating and cooling supply. Humidity control involves a compound controller for regulating heat and adjusting humidity by means of a steam or water spray.

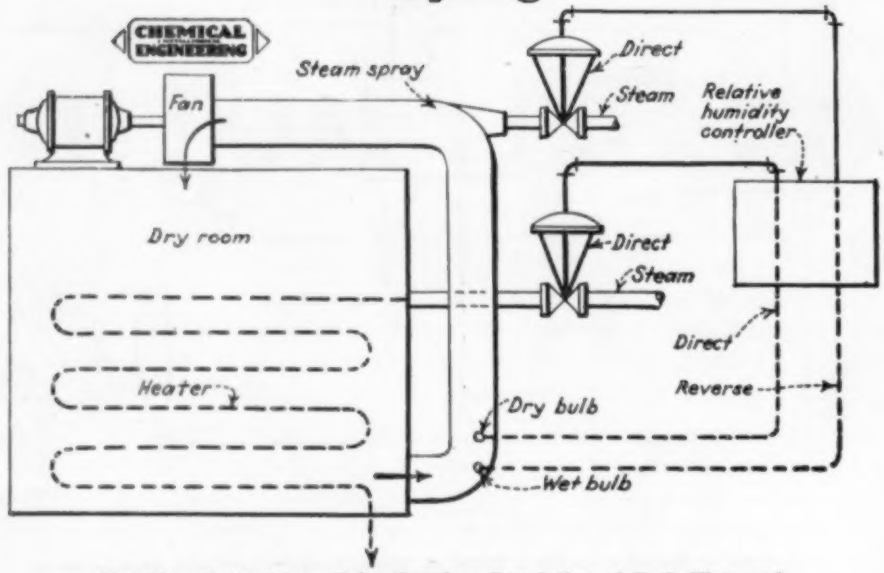
Several interesting applications of drying control are used in drying paper and other similar continuous webs. There is vacuum tube control which actually measures the moisture content of the paper and adjusts drier temperature accordingly. Another device has been used to accomplish the same result by continuously measuring the temperature rise of the web when a definite amount of heat is supplied, again adjusting the drier. Since shrinkage of the drying web must be kept within bounds, various methods have been applied to control this factor. In one, a floating roll over which the web passes tends to close a steam valve and reduce drying rate if the shrinkage becomes too great. In another, tension of



Control of a Vacuum Drier Usually Involves Only Regulation of Drier Temperature

This is easily accomplished with both fluid- and electrically-actuated thermometer controllers

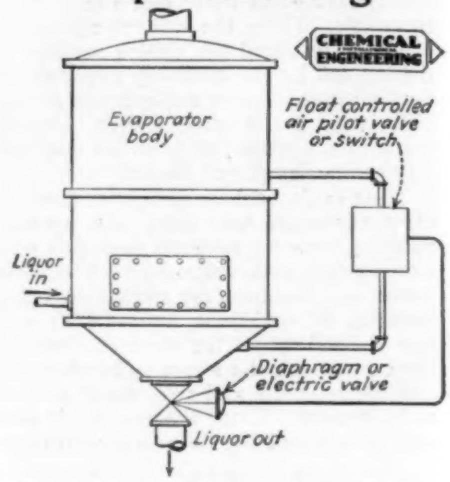
Drying



Humidity Control in a Drier Requires Regulation of Both Wet- and Dry-Bulb Temperature

This might also represent one constant-humidity section in a continuous drier of several such sections, each separately controlled

Liquid Handling



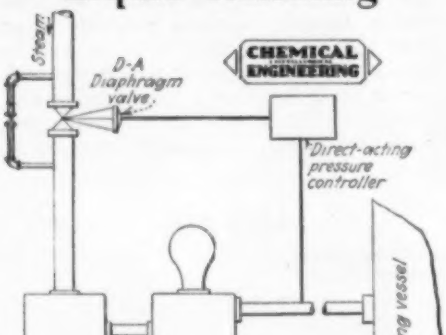
Level Control May Use a Float to Operate an Air Valve or Switch

The controlled valve or pump may be either in the inlet or outlet line

the web as it passes over a perforated pipe containing air under pressure permits a greater or lesser amount of air to escape and thus controls the pressure in the pipe. The air pressure in turn acts to adjust a variable speed drive and hence makes slight changes in speed in various sections of the drier, maintaining constant tension in this manner.

Still another control is intended to locate the web properly on the drier rolls in case differential shrinkage of the two edges of the web should pull it to one side of the drier. Here a pipe in contact with the web has several per-

Liquid Handling

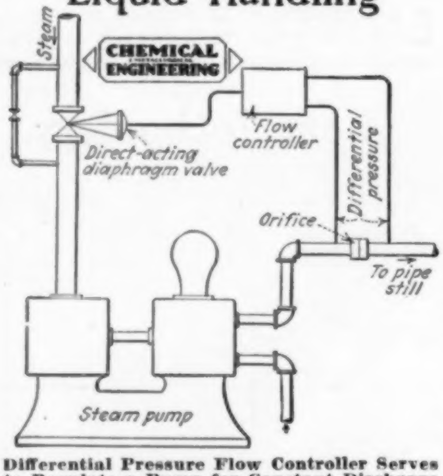


Such Pressure Controllers Adjust Steam to the Pump to Hold a Constant Discharge Pressure

This device is not intended to maintain constant discharge volume

forations at one edge of the paper so that when a vacuum pump exhausts the pipe, the degree of vacuum will depend upon the number of holes covered. A bellows attached to the line adjusts the angle of a set of swinging rolls through which the web is threaded, thus pulling the strip back into alignment until the correct number of holes is covered.

Liquid Handling



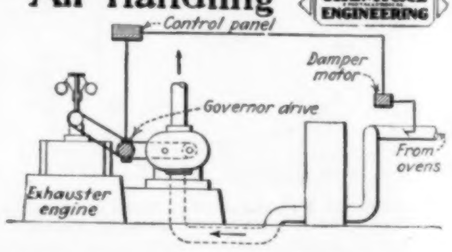
Differential Pressure Flow Controller Serves to Regulate a Pump for Constant Discharge Against Variable Pressure

Drop across the orifice is maintained constant

Liquid Handling. — Both flow and pressure control are encountered in liquid handling Liquid level is often a factor as well. Flow may be controlled by some other variable such as temperature, as for example, flow of cooling water to a condenser, but it most frequently involves control of flow *per se* and is accomplished with controlling flow meters of one type or another. Constant displacement pumps driven at a speed strictly under control may be used but particular attention is called to the various flow controllers which act to adjust the differential pressure across an orifice by setting the supply valve. Such controllers ordinarily use a manometer containing mercury which regulates the supply valve by means of air pressure or through a throttling electric valve.

Level control makes use of instruments that measure static pressure head or locate the level by means of a float,

Gas and Air Handling



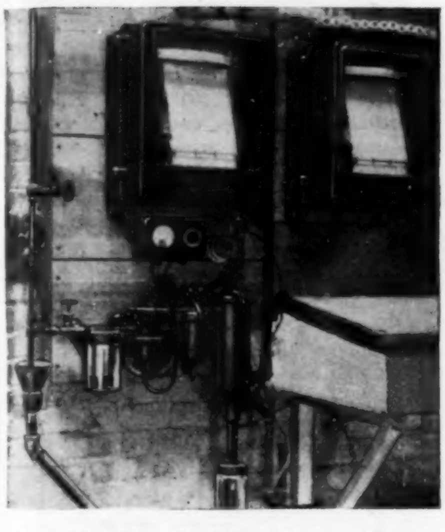
How Shallcross System Controls Exhauster Speed in a Gas Plant

If pressure fluctuations in the collecting main become out of control of the damper at the right, a variable speed drive between exhauster and engine governor is automatically adjusted to correct the engine speed

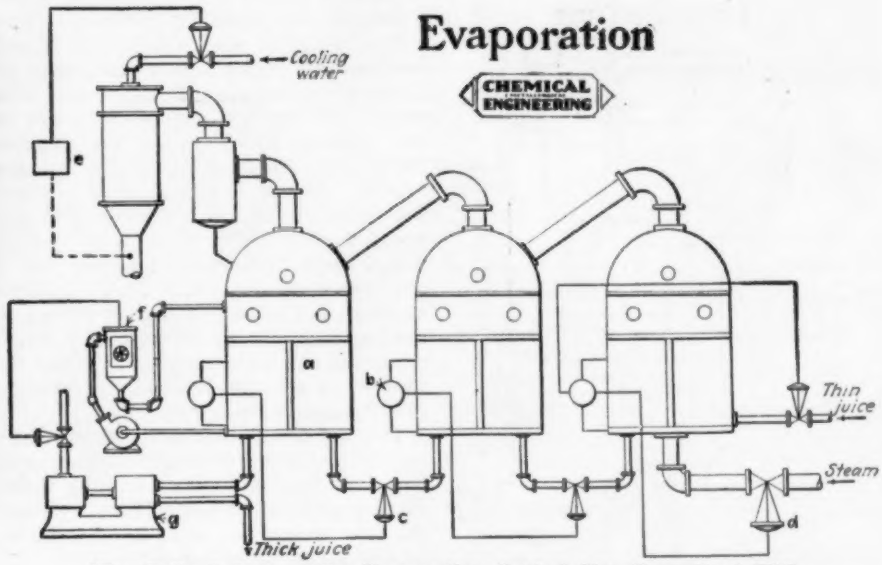
controlling a pump or valve by air or electricity. Level controllers are particularly useful in maintaining a constant head in a supply tank or removing liquid from a system which is under pressure.

Air and Gas Handling. — Under this head are many important applications

Air and Gas Handling—Brooke Flow Controller Adjusts Valves or Dampers Electrically to Maintain Constant Gas Flow

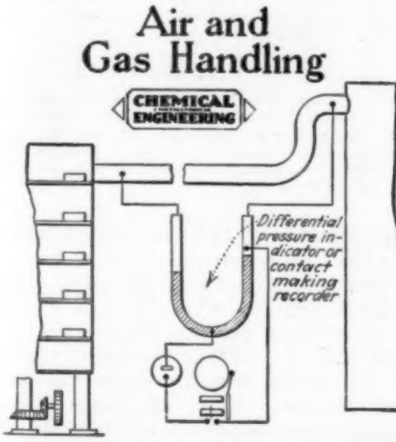


Air and Gas Handling—Gases May be Analyzed Continuously and Composition Recorded or Controlled
Engelhard thermal conductivity analyzer-recorder in a porcelain plant



"Tag-Bailey" Sugar Juice Evaporation Control Has Been Used With Quintuple-Effect Evaporators
Juice flowing through evaporators (a) is discharged at proper gravity by pump (g) controlled by gravity meter (f). Steam is shut off at (d) in event of juice supply failure while condenser water supply is controlled by regulator (e) to give most efficient condenser temperature. Level controllers (b) working with valves (c) maintain proper juice level.

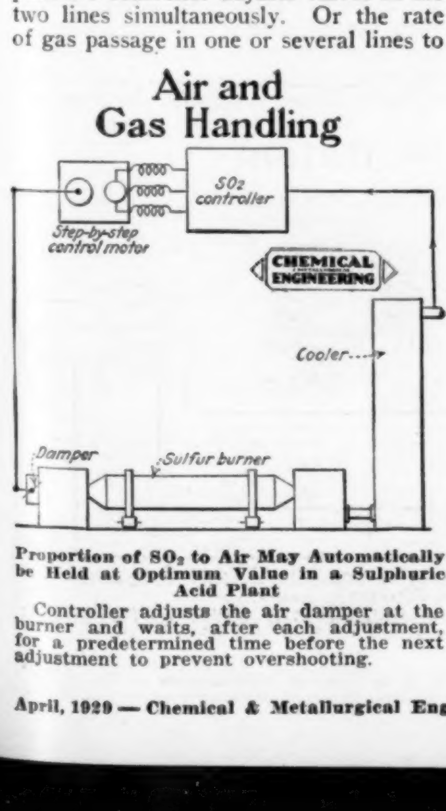
of gas flow control. An example is the control of gas and combustion air flow



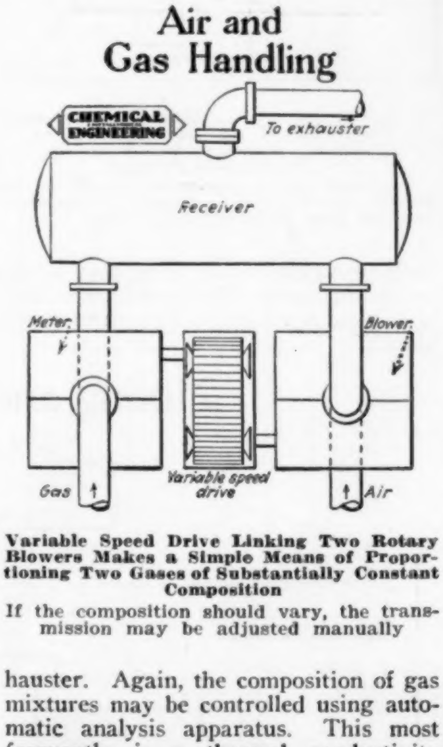
Differential Pressure Gage with Signalling Device Detects Flue Stoppage Due to Dust

to a heating process where a single temperature controller adjusts valves in the two lines simultaneously. Or the rate of gas passage in one or several lines to a process may be regulated by means of differential pressure flow controllers as in the synthesis of ammonia or its oxidation to nitric acid. Extremely accurate proportioning is necessary in these cases.

Other cases include the control of back pressure on a system which may involve only a simple pressure-controlled damper or may go to the extent of adjusting the speed of a blower or ex-



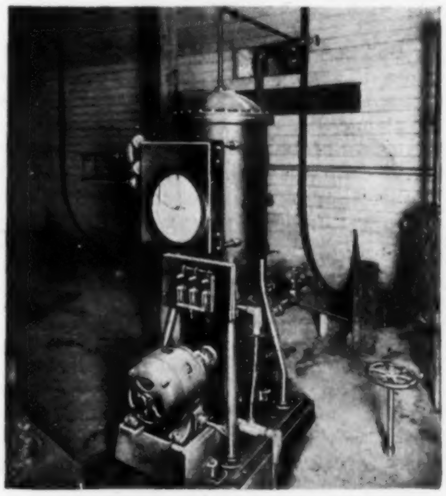
Proportion of SO_2 to Air May Automatically be Held at Optimum Value in a Sulphuric Acid Plant
Controller adjusts the air damper at the burner and waits, after each adjustment, for a predetermined time before the next adjustment to prevent overshooting.



Variable Speed Drive Linking Two Rotary Blowers Makes a Simple Means of Proportioning Two Gases of Substantially Constant Composition
If the composition should vary, the transmission may be adjusted manually

hauster. Again, the composition of gas mixtures may be controlled using automatic analysis apparatus. This most frequently is a thermal conductivity controller and is applied, for instance, in maintaining the proper supply of air to sulphur burners so as to give unvarying SO_2 content in the gases.

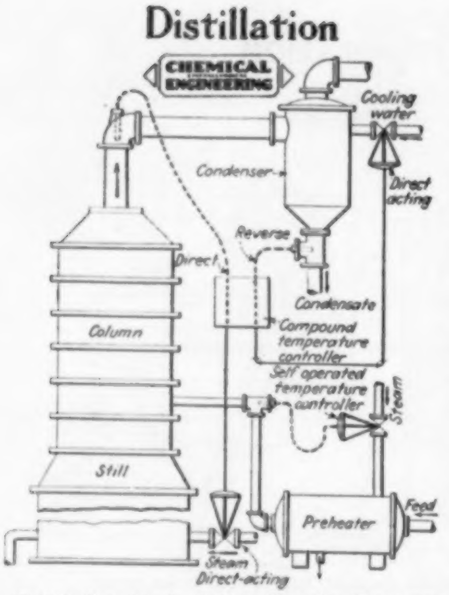
Evaporation.—This is a case for heat control but it may make use also of level



Evaporation—Bailey Gravity Recorder Operating "Tag" Air Valves to Control Evaporation of Sugar Juice

and specific gravity control as shown in the drawing of an installation for sugar juice evaporation in a large beet sugar plant. In this plant, which actually employed five effects, flow of juice to the evaporators *a* was controlled by level controllers *b* which were in turn controlled by the rate at which thick juice was withdrawn from the last effect. That is, as the level dropped in the last effect, its level controller opened valve *c*, admitting more juice and lowering the level in the preceding effect so that the same action occurred in each evaporator back to the first.

The level controller in the first effect had, as an additional feature, an extra air valve which served to close steam valve *d* whenever the supply of thin juice was insufficient. In the meantime, however, the controller *e* maintained a constant condenser temperature, and hence vacuum on the system, while the gravity controller *f* held the pump *g* at such a speed that the withdrawn juice was at a correct and unvarying con-



Distillation Control May Require Temperature Regulation at Several Points

Here a self-acting controller is shown regulating feed temperature while a compound temperature controller adjusts column and condenser temperatures

centration. In this particular installation a saving of over 11 per cent in steam was effected by the control system.

Distillation. — Distillation requires heat control and often flow and pressure control as well. Tube stills, for example, function properly only when an unvarying flow obtains regardless of pressure variation. Temperature must also be controlled. In vacuum distillations, pressure control enters, but is handled, as in evaporation, by means of the regulation of condenser temperature. For difficult fractionations, both reflux and feed temperatures may profitably be controlled while the necessity for close temperature regulation in the still itself is self-evident.

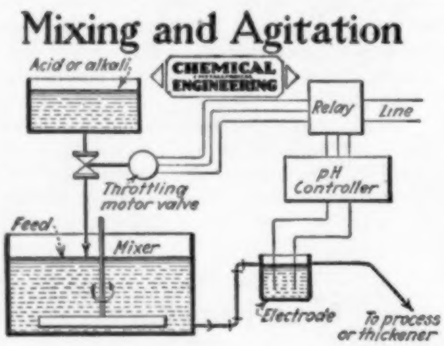
An example of pressure control as applied to distillation occurs in a large eastern alcohol plant where both exhaust and high-pressure steam are used to heat the stills. The supply of exhaust steam, which is quite irregular as it comes from reciprocating steam engines and compressors, is collected in a 16-in. header about 300 ft. long for distribution to the various stills. A very sensitive pressure controller admits 135-lb. steam to the header, and although this addition varies between 20,000 and 75,000 lb. per hour, maintains constant steam pressure for the stills.

Mixing and Agitation.—Control in this group usually requires automatic analysis of some sort unless the materials being mixed do not vary in composition, when proportioning pumps or flow controllers alone will suffice. In the case of solids, feeders are available for automatic weighing, while similar equipment, substituting automatic weigh tanks for conveyors or hoppers may be used for liquids.

When the composition of one or both ingredients varies, however, some very nice problems may arise, as in the case illustrated where gravity control solved a difficult impregnating problem. Here a film saturated with water was passed continuously into a tank *a* containing an organic impregnating liquid mixed with water. As the film gave up its water to the solution and absorbed the organic liquid, the solution naturally became diluted. Hence, it was allowed to overflow continuously to a sump *b* and was pumped from there to a head tank *c*, which was, however, shunted by a gravity controller *d*. This machine actuated the throttling motor valve *f* in the line from constant level tank *e* which contained the make-up liquid. Thus the feed to *a* was maintained at constant gravity and composition.

Or, another illustration shows how two gases of varying composition may be mixed to give constant heating value. Here a controlling calorimeter regulates the flow of one gas so as to give the required B.t.u. value for the mixture.

A third form of mixing control may be based upon conductivity as, for example, when it is desired to maintain a definite concentration of an electrolyte in a bath; or the pH value of a bath or of the liquid at one point in a continuous process may be controlled for some

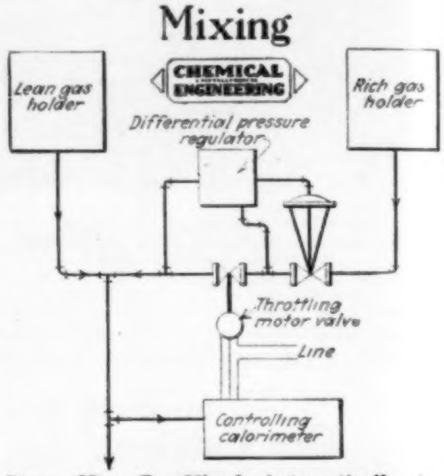


Control of pH May be Used for Continuous Neutralization or Maintenance of Constant Hydrogen-Ion Value in a Continuous Process

Constant pH of proper magnitude is desirable, for example, in securing maximum settling rate in thickening slimes.

definite concentration of acid or alkali, or for neutrality. This last form of control is also illustrated in an accompanying sketch.

Absorption.—Absorption may necessitate control of temperature, back-pressure on a tower, differential pressure across a tower or the proportioning of gases and liquids. For example, temperature control is usually of utmost importance in the use of the various solid adsorbants. Again, when a gas or vapor is absorbed in a liquid, in a tower for instance, a differential pressure regulator may be required. Or this may take the simple form illustrated where back-pressure control by means

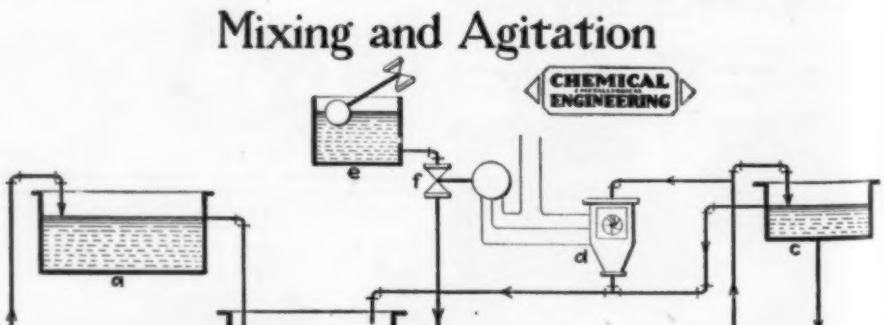


Gases May Be Mixed Automatically to Insure Unvarying Heating Value

A controller calorimeter adjusts the flow of one of two gases of variable composition so that the calorific power of the mixture remains unchanged

of a pressure regulator-controlled damper is all that is required.

One interesting example comes from a large refinery where it was desired to proportion the naphtha used to absorb still gas so that a definite amount of the liquid was available for each unit of gas. This was accomplished through the use of two orifice meters, one to measure the flow of each fluid. By means of a linkage between the recorders, a pen to record gas flow was added to the naphtha meter and a ratio contactor was provided which made contacts for more or less naphtha, depending upon whether the gas pen was above or below the naphtha pen. An electric throttle valve, controlled by the con-



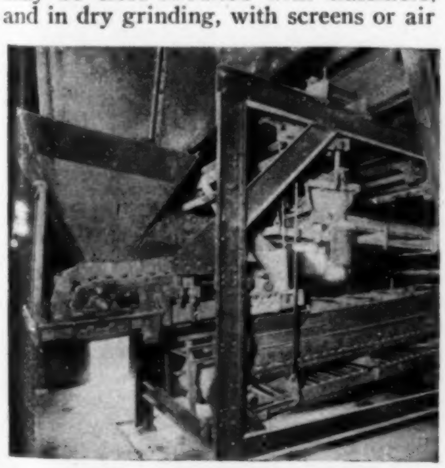
Specific Gravity Control Sometimes Serves to Maintain Desired Composition of a Liquid Mixture

In this installation, a Bailey electrically-operated gravity controller (d) controls feed rate of an organic liquid in (e) to maintain constant composition of the fluid in the circulating system (a), (b) and (c)

tacts and located in the steam line to the pump, adjusted the pump speed and hence the delivery of naphtha.

Material Handling.—In this field, automatic control is accomplished by the various feeders and proportioners of the weighing type. By means of these devices, which make use of both hoppers and belt conveyors it is possible to control the flow of solid materials within any required limits of accuracy.

Disintegration.—Disintegration is not usually considered as being susceptible to automatic control but a little consideration will show that the various types of close-circuit grinding are actually examples of very accurate automatic control. In wet grinding the mills may be close-circuited with classifiers, and in dry grinding, with screens or air

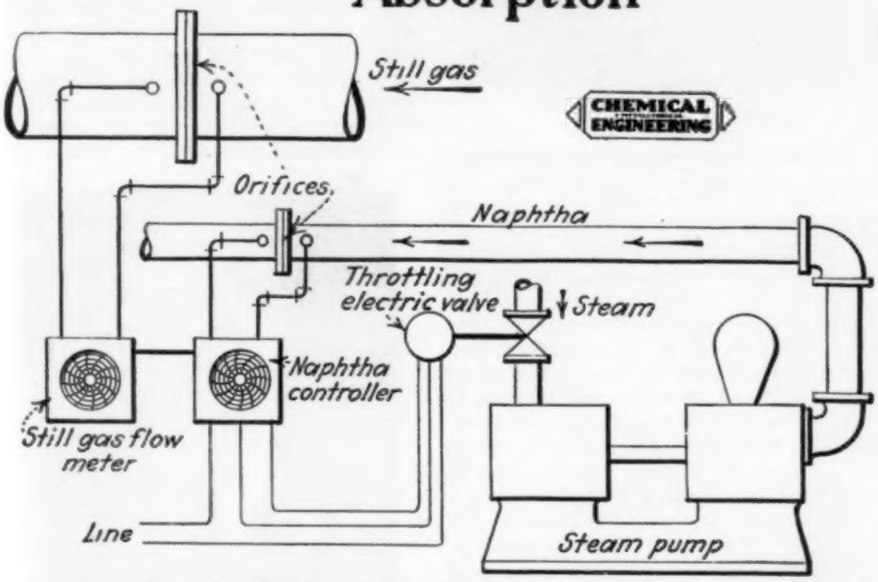


Material Handling — Proportioning Solid Materials or Controlling Rate of Flow May be Handled with Automatic Feeders Such as This Richardson "Conveyoweigh"

separators. In either case, feed control is, of course, required but this is provided by the various sorts of feeders previously discussed or in the case of one make of mill, by an automatic feeder which is controlled in its rate by the degree of vacuum in the air separator and hence by the performance of the mill.

There are still other applications of control in disintegration which, while somewhat unusual, have nevertheless been usefully applied in a number of instances. One was mentioned in the immediately preceding section of this issue in connection with ammeter control

Absorption

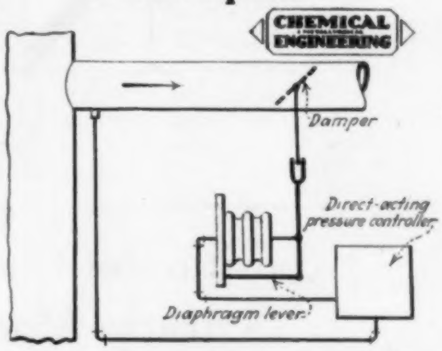


Absorption of Still Gas of Variable Quantity Requires Proper Proportioning of Absorbing-Naphtha Flow

Two Bailey orifice meters were used in this installation to control electrically the speed of the naphtha pump

of beaters and jordan engines in the paper mill. In these cases the clearance of the cutting surfaces is adjusted in accordance with ammeter readings for the proper disintegration of the stock. Although these controls are not automatically applied, they could easily be made so. Another somewhat similar application is the use of a contact-

Absorption



Back-Pressure on Absorption Towers Often Requires Control

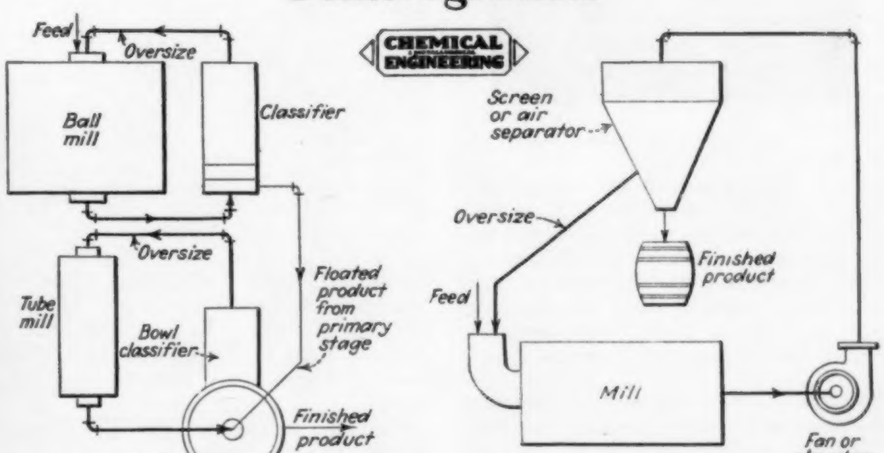
Damper regulation by means of a pressure controller accomplishes the result

making ammeter or wattmeter for controlling feed to grinding mills. Since the power consumption for a constant fineness of grinding varies as the feed, use of the control feature of the meter to regulate the speed of the feeder is an obvious method of obtaining this control.

One more application of control in disintegration comes to mind. This is not used in the actual grinding operation but serves rather as a check on the condition of the grinding media in ball or pebble mills. It has been found that an ammeter reading when the mill is running empty is an excellent indication of the weight of grinding medium present. It is possible to use this as a measure of the decrease in weight brought about by wear so that the operator is informed when an addition of balls is in order.

The preceding discussion has touched very briefly upon some few of the applications of control equipment to the various unit processes. It is to be hoped

Disintegration



Disintegration, Also, Has Its Automatic Control

Wet grinding may be handled as in (a) with Dorr classifiers and dry grinding, as in (b), by close-circuiting the mill with a screen or air separator

the cases mentioned will suggest others and that this relatively new field, automatic control, will come into its own in the chemical engineering industries as rapidly as economics justifies its further acceptance.

NEWS *of the* Industry

Exposition of Chemical Industries Attracts Many Exhibitors

Students Course and Banquet of Chemical Industries Included in Program

EVERYTHING is practically in readiness for the opening of the Twelfth Exposition of Chemical Industries which will be held at Grand Central Palace, New York City, during the week beginning May 6.

The exhibits promise to be of unusual interest as they will illustrate the progress that has been made in recent years in the development of new products and new processes in the chemical and allied fields. The exhibits fall under four general classifications—raw materials, finished products, machinery and equipment, and educational. Raw material displays will include agricultural, forest, mineral waste, by-products of manufacture, and undeveloped water powers. Finished products comprise chemicals, dyes, solvents, and such products as plastics, lacquers, varnishes, and coverings for acid.

Charles F. Roth

EXHIBITS of machinery and equipment will embrace materials of construction, machines, equipment, and apparatus for the plant and laboratory. Instruments of precision for control of temperature, pressure, volume, time rate and flow, weighing and measuring. Auxiliary equipment, numerous types of special mechanical equipment, supplies and commodities which may be classed either as utility or service articles.

Educational exhibits will demonstrate the results of most recent research on the part of government agencies, quasi-government departments, and large industrial and technical organizations.

PROMINENT among the features of the exposition will be the students course on the fundamentals of industrial chemistry and chemical engineering practice. This course will be under the direction of Prof. W. T. Read of the Texas Technological College. The program for the students course includes:

Group I — Disintegration — Lincoln T. Work, Columbia University, "Grinding"; Pierce M. Travis, Travis Colloid Research Co., "Colloid Mills."

Mechanical Separation—Everett P. Partridge, "Industrial & Engineering Chemistry," "Dust Collection"; Arthur Wright, Filtration Engineers "Filtration"; H. L. Olin, State University of Iowa, "Filter Aids: Their Nature and Use."

Separation with Phase Change—Philip DeWolf, Goslin-Birmingham Mfg. Co., "Evaporation."

Process Control — Arthur Schroder, Fisher Scientific Co., "Laboratory Apparatus for Controlling Plant Operations"; Richard Rimback, Editor "Instruments," "Automatic Process Control Instruments and Devices"; James R. Withrow, Ohio State University, "Temperature Measurement and Control."

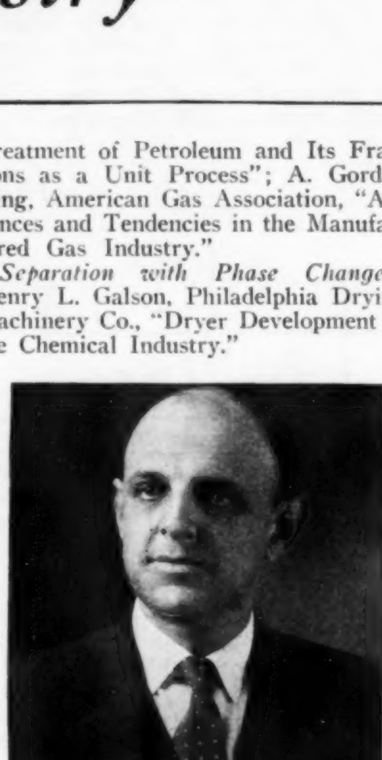
Unit Processes—A. Anable, The Dorr Company, "Conversion of Batch Processes to Continuous"; A. B. McKechnie, Parks-Cramer Co., "Heat Transference with Oil."

Materials of Construction—S. L. Tyler, Thermal Syndicate, "Use of Vitreosil in the Manufacture of Sulphuric, Nitric, and Hydrochloric Acids"; John R. Townsend, Bell Telephone Laboratories, "Non-Ferrous Materials."

General Addresses—H. E. Brown, W. M. Welch Scientific Co., "Use of the Element Charts in Laboratory and Works"; W. H. Huson, Carboloy Co., Inc., "Laboratory Side of the Manufacture of Carboloy and Elkonite"; Williams Haynes, Publisher "Chemical Markets," "Business Chemistry."

Group II—Reviews of Industries—Allen Rogers Pratt Institute, "An Outline of Recent Advances in the Manufacture of Leather"; J. C. Morrell, Universal Oil Products Co., "Chemical Treatment of Petroleum and Its Fractions as a Unit Process"; A. Gordon King, American Gas Association, "Advances and Tendencies in the Manufactured Gas Industry."

Separation with Phase Change—Henry L. Galson, Philadelphia Drying Machinery Co., "Dryer Development in the Chemical Industry."



Prof. W. T. Read

Process Control—B. P. Romaine, Weston Electrical Instrument Co., "Electrical Instruments in the Chemical Industries"; Isman Ginsberg, "Automatic Control of Temperature in the Chemical Industries."

Materials of Construction — Jerome Strauss, Vanadium Corp. of America.

ON Wednesday afternoon, May 8, at 2 p.m. the Technical Association of the Pulp & Paper Industry will hold a meeting, and among the speakers will be J. Dilot, A. O. Smith Corp., "Welded Pressure Digesters"; M. W. Meyer, Anti-Hydro Waterproofing Co., "An Improved Paper Mill Concrete Floor"; Lee Wallis Gibbons, "High Chrome High Nickel Stainless Alloys in the Sulphite Process"; Charles Fuhrmeister, Jr., Oliver United Filters, Inc., "Continuous Filters Featuring Insulating Board Machines"; F. E. Huggins, Jr., Sowers Mfg. Company, "Seamless Jacketed Mixers for Cutting Casein"; F. J. Shepard, Lewis-Shepard Co., "Shipping on Skid Platforms."

Thursday evening, May 9, is the date set for the Sixth Annual Chemical Industries Dinner at the Roosevelt Hotel. The dinner is sponsored by the Salesmen's Association of the American Chemical Industry.

The exposition will be under the direction of the International Exposition Company of New York of which Charles F. Roth is manager.

Major-General Gilchrist Heads C.W.S.

THE NEWLY appointed Chief of the Chemical Warfare Service, Major-General Harry L. Gilchrist, has been connected with this branch of national defense for ten years. He was prominent in its pioneer organization and participated in nine of the different engagements in which the Chemical Warfare Service took part.

General Gilchrist was born in Iowa, January 16, 1870. He took the medical course at Western Reserve University and later attended the army medical school, from which he was graduated in 1903, as its medalist. He served with the Medical Corps of the army continuously until the World War, when he was appointed a colonel in the national army.

Before he was assigned to the Chemical Warfare Service he was in command of British hospital No. 9 at Rouen, where thousands of gas cases from the British fronts were handled. To familiarize himself with gas warfare methods he went with the advance lines on several occasions. The bravery he displayed in getting close enough to the Germans to secure valuable information resulted in his being mentioned by the British for gallantry in action. While with the British army he took the chemical warfare course for line officers and was graduated with the class.

His principal contributions to the technical side of chemical warfare follow: Devised a method of detecting the presence of mustard gas on exposed surfaces; devised a method of neutralizing mustard gas, both vapor and liquid; devised and perfected the demustardizing gas bag for small organizations; devised a method of using the G.I. can for the purpose of removing mustard from clothing and small equipment; devised method of removing mustard vapors from enclosed areas; devised method of using the regulation ambulance as a degassing chamber; devised a simple field apparatus for measuring pressure gases.

It was General Gilchrist who was in command of the American Relief Association's expedition into Poland to assist in meeting the typhus epidemic there.

In addition to the distinguished service medal of the United States, General Gilchrist has decorations and citations from Great Britain, France, and Poland.

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Major-General Harry L. Gilchrist

Record Production of Dyes in 1928

PRELIMINARY figures compiled by the United States Tariff Commission show that the domestic production of coal-tar dyes for the calendar year 1928 exceeds that for 1927 by approximately 1,400,000 lb., and that progress in the manufacture of fast and specialty dyes has continued. In 1928, dyes of domestic production supplied about 92 per cent of our consumption by quantity and there was, in addition, an exportable surplus of the bulk low-cost colors amounting to over 32,000,000 lb.

Production by 47 firms of approximately 96,600,000 lb. was an increase of 1.5 per cent over the production in 1927. Sales of dyes in 1928 were 93,300,000 lb. valued at $39,790,000. The quanity of sales shows a decrease of 5 per cent from 1927; the value of sales shows an increase of 3.3 per cent.

Outstanding features of American dye production in 1928 were: increase in production of vat and other fast dyes; production of many new fast and specialty dyes; reduction of the number of domestic manufactures from 55 to 47; increase in unit price of sales of all dyes; increase in exports; increase in dye imports.

Processes Developed To Bind Fixed Nitrogen

AN interesting series of processes utilizing phosphate rock to bind fixed nitrogen has recently been introduced into this country by the Dorr Company, Inc. The processes were developed by Frans G. Liljenroth, a prominent Swedish engineer whose name has been associated with some of the pioneer work in developing phosphoric acid technology.

Kunstdunger Patent Verwertungs A.G., of Switzerland, has been formed as a patent holding corporation and will continue research work in connection with nitrogen binding and the production of concentrated synthetic fertilizers.

The Dorr-Liljenroth processes bind from 20 per cent to 70 per cent of the nitrogen in the form of concentrated mixed fertilizers containing from 40 per cent to 70 per cent total plant food and the remainder as ammonium sulphate and calcium nitrate containing from 14 per cent to 21 per cent nitrogen.

It is claimed that the over-all binding cost of a plant with a capacity of from 20,000 to 25,000 tons of ammonia per year will be from 0.6 to 1.2c. per lb. depending on the type of materials produced.

Wood Chemical Interests Form Institute

AT A meeting of representatives of the hardwood distillation industry in the Statler Hotel, Buffalo, March 21, initial steps were taken for organization of a trade association for the industry. A substantial proportion of the total capacity of the industry is included in the temporary organization and other units will be taken in as the organization work proceeds.

The association will be incorporated at an early date as the Wood Chemical Institute. Temporary officers and directors have been elected as follows: President, W. L. Heim; vice-president, W. J. Merwin; secretary-treasurer, L. T. Kniskern; directors, M. C. Burt, Gray Chemical Company, Roulette, Pa.; F. F. Clawson, Clawson Chemical Company, Ridgeway, Pa.; W. Z. Georgia, Buckhannon Chemical Company, Olean, Pa.; W. L. Heim, Otto A. Kerry, Custer City Chemical Company, Bradford, Pa.; L. T. Kniskern, receivers of the Charcoal Iron Company of America, operating as James T. Leary & Co., Chicago; J. A. McCormack, Union Charcoal & Chemical Company, Olean, N. Y.; W. J. Merwin, Thomas Keery Company, Hancock, N. Y.; M. F. Quinn, Vandalia Chemical Company, Olean, N. Y.; C. A. Saunders, Cadillac-Soo Lumber Company, Sault Ste. Marie, Mich.; John Troy, Heinemann Chemical Company, Olean, N. Y.

Temporary offices have been established in room 859, 231 South LaSalle Street, Chicago.

Texas Gulf Sulphur Opens New Plant

PRODUCTION of sulphur at the Boling dome, Newgulf, Texas, was started by the Texas Gulf Sulphur Company in the latter part of March. Operation of the new plant began almost exactly two years after the first disclosure, by drilling, of the possibility that sulphur might be developed in quantity.

The exploratory drilling campaign involved the sinking of about 250 wells, the depth of which varies from 500 to 2,000 ft. In this way the approximate edges of the deposit have been determined as closely as is possible, in view of the mode of occurrence of the sulphur, and a basis for calculating the probable tonnage has been obtained. Data thus collected indicate that the deposit contains several times as much sulphur as the deposit in the Big Hill dome at Gulf. The Boling dome in which the sulphur occurs is probably the largest salt dome ever found, being over 4 miles long in a north and south direction and about 3 miles wide, as determined by geophysical methods.

In addition to the operating plant, a modern town of more than 300 dwellings, provided with all facilities, has been built.

Germany Regaining Position in Dye Markets

THROUGH the operation of international cartels, Germany has gone a long way toward regaining her former dominence in world dye markets, it is shown by Trade Information Bulletin 605 recently published by the Commerce Department. The pamphlet reads in part:

"Germany controlled 80 per cent of the world's prewar market for dyes and supplied most of the intermediates entering manufacture of the other 20 per cent. This favored position has been broken by postwar developments elsewhere so that Germany can now claim only 40 to 45 per cent of the world market in competition with American, French, British, and Swiss producers. German production is estimated at 80,000 tons now against the prewar figure of 140,000 tons.

"But," the bulletin continues, "Germany's interest in dyestuffs production in other countries, including cartel market-sharing agreements, are far reaching and one German economist has claimed that Germany controls 72 per cent of the world market in this way. Its international agreements include a joint manufacturing arrangement with a large American firm."

During the past year, according to the pamphlet, the German dye trust, representing a third of the nation's chemical output, arrived at agreements with French, Swiss, British, and Italian chemical concerns and acquired a half interest in a large American photo-chemical plant. It ratified the Franco-German dye pact of 1927. Among other activities, the I.G. is an important producer of rayon.

New Chemical Laboratory Opened at Harvard

THE Mallinckrodt and Converse Memorial to Harvard University, a $2,000,000 chemical laboratory, was formally opened at Cambridge, Mass., on April 8, in the presence of a gathering of scientists and representatives of the chemical industry. Speakers at the reception were President Lowell, Prof. G. P. Baxter, chairman of the division of chemistry, and Dean Wallace B. Donham of the Harvard business school, executive chairman of the committee for the raising of the funds for the new plant.

Kalbfleisch Absorbs Firm of J. C. Wiarda & Co.

BEGINNING April 1, the business of John C. Wiarda & Co., Inc., Brooklyn, will be conducted as the John C. Wiarda & Co. division of The Kalbfleisch Corporation, 200 Fifth Avenue, New York, the latter company having acquired the capital stock of the former.

George E. Taylor, general manager for the Wiarda company, will continue in the same capacity with the new organization. Howard B. Bishop, president of the Wiarda company, has withdrawn his connection and will devote his attention to the Sterling Products Company, Easton, Pa. The Wiarda company was established in 1871.

The Kalbfleisch Corporation celebrated its one hundredth anniversary last month.

Symposium on Welding in Chemical Industries

THE annual meeting of the American Welding Society will be held at the Engineering Societies Building, New York on April 24-26. The meeting will open on the morning of April 24 with a business session at which F. T. Llewellyn, president of the society will preside. This will be followed by technical sessions which will run throughout the three-day meeting. Of particular interest will be the session on the morning of April 26, which will be devoted to a symposium on welding in the chemical and process industries. The program includes "Welding Aluminum in the Chemical Industry" by W. M. Dunlap, Aluminum Company of America; "The Production of Ductile Welds in Nickel and Monel Metal" by N. B. Pilling, International Nickel Company; "Welding of Pressure Vessels for High Temperature and Pressures" by T. McLean Jasper, A. O. Smith Corporation; "Welding in the Chemical and Process Industries" by A. G. Wikoff, Carbide & Chemical Corporation; and "Welding Duriron" by P. D. Schneck, the Duriron Company, Inc.

Xylose Plant Operating at Anniston, Alabama

THE xylose factory at Anniston, Ala., started operating on March 16. On that date there were produced 35 pounds of white crystalline xylose. This factory is operated on a co-operative basis by the Alabama Polytechnic Institute, the University of Alabama, the Federal Phosphorus Co., and the Bureau of Standards. All of the equipment is not yet in place, so that the factory is not in full production. It is designed to produce 100 pounds of xylose per day.

New York Paint Club Will Elect Officers

On May 9, the Paint, Oil, and Varnish Club of New York will hold its annual meeting at the Hotel Biltmore. Officers will be elected for the ensuing year. The nominating committee has proposed the following: president, J. W. Robson, Standard Varnish Works; vice-president, W. R. Morpeth, E. I. du Pont de Nemours & Co.; secretary, David H. Litter, D. H. Litter Company; treasurer, H. E. Hendrickson, S. Winterbourne & Co.

Synthetic Ammonia Plant for Soviet Union

PLANS for the construction in the Soviet Union of a $10,000,000 factory to produce synthetic ammonia and other fertilizer materials, are being prepared by the Nitrogen Engineering Corporation of New York. The contract calling for the technical assistance of the American firm in the construction and operation of the plant was ratified by the Soviet Government in February, according to an announcement made by Dr. L. C. Jones, of the Nitrogen Engineering Corporation, and Saul G. Bron, chairman of the board of directors of the Amtorg Trading Corporation.

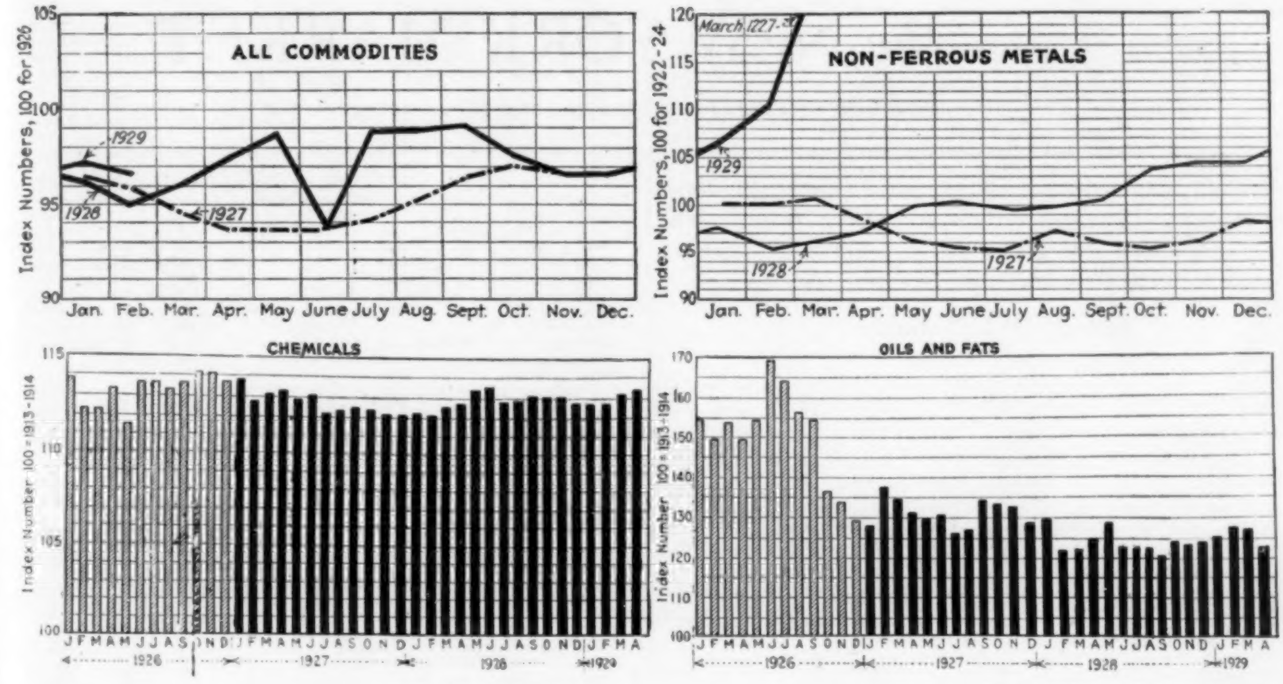
This new synthetic fertilizer plant is a part of the projected expansion of the chemical industry of Russia, which is being planned by the Soviet Government for the next five years. Prof. P. A. Tchekin, vice-president of the Chemical Construction Company of U.S.S.R., has recently been in the United States making a study of American chemical developments, and at a meeting before the Russian Association of Engineers held in New York on March 18, he announced the detailed plans for this expansion and indicated that the Soviet Government was looking to American and European engineering firms to supply not only the technical assistance, but a considerable proportion of the equipment and machinery required for the new chemical plants.

British Company Acquires Carbonization Patent

IN A report from London, trade commissioner Homer S. Fox states that the Parent Coal Carbonization Trust (Ltd.) has been formed with a capital of £750,000 to acquire the rights for Great Britain of the Aicher low-temperature carbonization process, to erect installations in Great Britain, to finance the erection of plants and rotary ovens at selected British collieries, to form subsidiary companies to deal with special coal areas in Great Britain and for other purposes.

The Aicher process was developed in Germany by Alfred Aicher, and 5 units of 120 tons daily capacity each are claimed to have been in operation at the Thyssen Works at Mulheim on the Ruhr, with satisfactory results. As the process is a secret one, the new company has secured Mr. Aicher's services for a period of 10 years. The process is claimed to be specially suitable for the treatment of cannel coal, and a contract has been made for the supply of 5,000,000 tons of cannel coal from the Argyll collieries, Campbelltown, Scotland, for delivery for a period of 15 years at 13s. 6d. per ton, delivered at pit head. The company proposes to erect an initial installation with a capacity of 1,000 tons daily, the first unit of 100 tons daily being expected to be in operation within six months.

CHEM. & MET. *Weighted Indexes of* PRICES



U. S. Dep't of Labor — *Engineering & Mining Journal*

Values for Chemicals Reach Higher Average Levels

WHILE most of the chemicals which are very important from a tonnage standpoint have been holding a steady price position, fluctuations in other selections have worked in favor of a higher average level. Competition among sellers is less pronounced than in former years and changes in sales prices are influenced mainly by variations in producing costs.

Metal salts have shown an irregular price trend during the month under the influence of unstable markets for metals. For the greater part of the period, the trend was upward, but toward the close lead and copper lost part of earlier gains and the salts likewise developed an easier tone.

One of the features of the market so far this year has been the continuous movement of heavy chemicals against contracts. This continued throughout last month and deliveries of alkalies, acids, etc., for the first quarter of the year undoubtedly excelled in volume, those for the corresponding period of 1928. Buying for new account also has been satisfactory and spot supplies of some chemicals are practically depleted.

THE position of producing and consuming industries has been such as to permit a large volume of output without an accumulation of unsold stocks. In many cases production so far this year, has been maintaining itself ahead of that for the corresponding period of last year. The following figures give some comparisons for production and consumption in February:

Production	Feb. 1928	Feb. 1929
Acetate of lime, 1,000 lb.	11,717	11,266
Alcohol, ethyl, 1,000 gal.	11,220	13,830
Methanol, crude, gal.	642,855	676,672
Methanol, refined, gal.	390,099	449,800
Nitrate of soda, Chile, ton	236,600	255,500
Turpentine, wood, bbl	5,645	6,436
Rosin, wood, bbl.	32,892	33,152
By product coke, 1,000 tons	3,723	4,090
Plate glass, 1,000 sq. ft.	10,093	11,289
Glass containers, 1,000 gross	2,085	2,261
Explosives, 1,000 lb.	31,895	35,392
Chemical wood pulp, tons	209,820	211,558
Consumption		
Cottonseed oil, bbl.	274,137	279,080
Wool in textile trade, grease equivalent, 1,000 lb.	48,324	47,993
Cotton in textile trade, bales	572,875	598,098
Petroleum, run to stills, 1,000 bbl.	66,625	72,031

Among other industries which have a bearing on consumption of chemicals and related products, it is noted that production of automobiles in this country and Canada reached a total of 595,000 in March which exceeds by 20 per cent the total for any preceding month. Tire manufacturers in the United States produced 6,911,590 pneumatic casings in February. The tire industry is estimated to have consumed a total of 76,744,858 lb. of crude rubber in that month.

IN ADDITION to the large demand for chemicals which comes from domestic consuming interests, there has been a wider interest on the part of foreign buyers and it is stated that export shipments for the first quarter of this year for the chemical group as a whole were nearly 10 per cent larger than for the first quarter of 1928. The soda group has contributed in no slight degree to the gain in export trade as may be seen from the fact that outward shipments for the first two months of the year amounted to 109,963,149 lb. compared with 83,166,679 lb. in the first two months of last year.

Chem. & Met. Weighted Index of Chemical Prices

Base = 100 for 1913-14

This month	113.31
Last month	113.15
April, 1928	112.72
April, 1927	113.34

The metal salts especially lead carbonate; lead oxides, and copper suiphate and carbonate were advanced in price during the month and the weighted index number was higher. Basic chemicals maintained a steady price position.

Chem. & Met. Weighted Index of Prices for Oils and Fats

Base = 100 for 1913-14

This month	123.14
Last month	127.39
April, 1928	124.90
April, 1927	131.67

Under the leadership of cottonseed oil and linseed oil, the price trend for oils and fats was downward. Corn, palm, and peanut oils also developed weakness and sales of tallow went through below the levels maintained in the preceding month.

CURRENT PRICES *in the* NEW YORK MARKET

For Chemicals, Oils and Allied Products

The following prices refer to round lots in the New York Market. Where it is the trade custom to sell f.o.b. works, quotations are given on that basis and are so designated. Prices are corrected to April 15.

Industrial Chemicals

		Current Price	Last Month	Last Year
Acetone, drums	lb.	$0.14 -$0.15	$0.14 -$0.15	$0.13 -$0.14
Acid, acetic, 28%, bbl.	cwt.	3.88 - 4.03	3.88 - 4.03	3.38 - 3.63
Boric, bbl	lb.	.06½- .07	.06½- .07	.08½- .08½
Citric, kegs	lb.	.46 - .47	.46 - .47	.46 - .47
Formic, bbl.	lb.	.11 - .12	.11 - .12	.11 - .12
Gallic, tech., bbl	lb.	.50 - .55	.50 - .55	.50 - .55
Hydrofluoric 30% carb.	lb.	.06 - .07	.06 - .07	.06 - .07
Lactic, 44%, tech., light, bbl.	lb.	.11½- .12	.11½- .12	.13 - .13½
22%, tech., light, bbl.	lb.	.05½- .06	.05½- .06	.06 - .07
Muriatic, 18°, tanks	cwt.	.85 - .90	.85 - .90	.85 - .90
Nitric, 36°, carboys	lb.	.05 - .05½	.05 - .05½	.05 - .05½
Oleum, tanks, wks.	ton	18.00 -20.00	18.00 -20.00	18.00- 20.00
Oxalic, crystals, bbl.	lb.	.11 - .11½	.11 - .11½	.11 - .11½
Phosphoric, tech., c'bys.	lb.	.08½- .09	.08½- .09	.08½- .09
Sulphuric, 60°, tanks	ton	11.00 -11.50	11.00 -11.50	11.00 -11.50
Tannic, tech., bbl	lb.	.35 - .40	.35 - .40	.35 - .40
Tartaric, powd., bbl	lb.	.38 - .39	.38 - .39	.38 - .39
Tungstic, bbl	lb.	1.00 - 1.20	1.00 - 1.20	1.00 - 1.20
Alcohol, ethyl, 190 p'f., bbl.	gal.	2.68½- 2.71	2.68½- 2.71	2.68½- 2.71
Alcohol, Butyl, dr	lb.	.17¾- .18	.17¾- .18	.19 - .20
Denatured, 190 proof				
No. 1 special dr	gal.	.48 -......	.48	.43 -......
No. 5, 188 proof, dr.	gal.	.48 -......	.48	.43 -......
Alum, ammonia, lump, bbl.	lb.	.03½- .04	.03½- .04	.03½- .04
Chrome, bbl	lb.	.05½- .05¾	.05½- .05¾	.05½- .06
Potash, lump, bbl.	lb.	.03 - .03½	.03 - .03½	.02¾- .03½
Aluminum sulphate, com., bags	cwt.	1.40 - 1.45	1.40 - 1.45	1.40 - 1.45
Iron free, bg	cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Aqua ammonia, 26°, drums.	lb.	.03 - .04	.03 - .04	.03 - .04
Ammonia, anhydrous, cyl.	lb.	.14 -......	.14 -......	.13½-......
Ammonium carbonate, powd. tech., casks	lb.	.12 - .13	.12 - .13	.10½- .14
Sulphate, wks	cwt.	2.35 -......	2.35 -......	2.60 -......
Amylacetate tech., drums	gal.	1.75 - 2.00	1.75 - 2.00	1.75 - 2.00
Antimony Oxide, bbl	lb.	.10½- .10¾	.10½- .10¾	.13½- .15
Arsenic, white, powd., bbl.	lb.	.04 - .04½	.04 - .04½	.04 - .04½
Red, powd., kegs	lb.	.09 - .10	.09 - .10	.09½- .10
Barium carbonate, bbl.	ton	58.00 -60.00	58.00 -60.00	48.00 -50.00
Chloride, bbl.	ton	65.00 -67.00	65.00 -67.00	55.00 -58.00
Nitrate, cask	lb.	.08½- .09	.07½- .08	.08 - .08½
Blanc fixe, dry, bbl	lb.	.03½- .04	.03½- .04	.04 - .04½
Bleaching powder, f.o.b., wks., drums	cwt.	2.00 - 2.10	2.00 - 2.10	2.00 - 2.10
Borax, bbl.	lb.	.02½- .03	.02½- .03	.04 - .04½
Bromine, cs	lb.	.45 - .47	.45 - .47	.45 - .47
Calcium acetate, bags	cwt.	4.50 -......	4.50 -......	3.50 -......
Arsenate, dr.	lb.	.06½- .07	.06½- .07	.06½- .07
Carbide drums	lb.	.05 - .06	.05 - .06	.05 - .06
Chloride, fused, dr., wks.	ton	20.00 -......	20.00 -......	20.00 -......
Phosphate, bbl.	lb.	.08 - .08½	.08 - .08½	.07 - .07½
Carbon bisulphide, drums	lb.	.05 - .06	.05 - .06	.05 - .06
Tetrachloride drums	lb.	.06½- .07	.06½- .07	.06½- .07
Chlorine, liquid, tanks, wks.	lb.	.03 - .03½	.03 - .03½	.03½- .04½
Cylinders	lb.	.05 - .08	.05 - .08	.05½- .08
Cobalt oxide, cans	lb.	2.10 - 2.20	2.10 - 2.20	2.10 - 2.25
Copperas, bgs., f.o.b. wks.	ton	15.00 -16.00	16.00- 17.00	16.00 -17.00
Copper carbonate, bbl	lb.	.19 - .21	.18½- .19	.18½- .19
Cyanide, tech., bbl	lb.	.49 - .50	.49 - .50	.49 - .50
Sulphate, bbl.	cwt.	6.50 - 6.60	6.20 6.40	5.05 - 5.15
Cream of tartar, bbl.	lb	.27½- .28	.27½- .28	.25¾- .27
Diethylene glycol, dr.	lb.	.10 - .15	.10 - .15	.10 - .15
Epsom salt, dom., tech., bbl.	cwt.	1.75 - 2.15	1.75 - 2.00	1.75 - 2.00
Imp., tech., bags	cwt.	1.15 - 1.25	1.15 - 1.25	1.15 - 1.25
Ethyl acetate, drums	gal.	1.03 -......	1.03 -......	.83 -......
Formaldehyde, 40%, bbl.	lb.	.09½- .10	.09½- .10	.08½- .09
Furfural, dr.	lb.	.15 - .17½	.15 - .17½	.15 - .17
Fusel oil, crude, drums	gal.	1.30 - 1.40	1.30 - 1.40	1.30 - 1.40
Refined, dr.	gal.	1.90 - 2.00	1.90 - 2.00	2.50 - 3.00
Glaubers salt, bags	cwt.	1.10 - 1.20	1.10 - 1.20	1.00 - 1.10
Glycerine, c.p., drums, extra.	lb.	.15½- .16	.15 - .16	.15 - .16
Lead:				
White, basic carbonate, dry, casks	lb.	.09 -......	.08¾-......	.08½-......
White, basic sulphate, sck.	lb.	.08½-......	.08 -......	.07¾-......
Red, dry, sck	lb.	.10½-......	.11 -......	.09½-......
Lead acetate, white crys., bbl.	lb.	.14 - .14½	.14 - .14½	.13 - .13½
Lead arsenate, powd., bbl.	lb.	.13 - .14	.13 - .14	.12 - .13
Lime, chem., bulk	ton	8.50 -......	8.50 -......	8.50 -......
Litharge, pwd., csk	lb.	.09¾-......	.09¾-......	.08½-......
Lithopone, bags	lb.	.05½- .06	.05½- .06	.05½- .06½
Magnesium carb., tech., bags.	lb.	.06 - .06½	.06 - .06½	.07½- .08
Methanol, 95%, dr.	gal.	.55 -......	.55 -......	.43 -......
97%, dr.	gal.	.55 -......	.55 -......	.45 -......
Nickel salt, double, bbl.	lb.	.13 - .13½	.13 - .13½	.10 - .10
Single, bbl.	lb.	.13 - .13½	.13 - .13½	.10½- .11½
Orange mineral, csk.	lb.	$0.12¾-......	$0.12¾-......	$0.11½-......
Phosphorus, red, cases	lb.	.55 - .57	.55 - .57	.62 - .65
Yellow, cases	lb.	.32 - .33	.32 - .34	.32 - .33
Potassium bichromate, casks.	lb.	.08½- .08½	.08½- .08¾	.08½- .08½
Carbonate, 80-85%, calc., csk.	lb	.05¾- .06	.05¾- .06	.05¾- .06
Chlorate, powd.	lb.	.07½- .08½	.07½- .08½	.08½- .09
Cyanide, cs.	lb.	.52 - .55	.52 - .55	.55 - .57
First sorts, csk.	lb.	.08¾- .09	.08¾- .09	.08¾- .09
Hydroxide(c'stic potash)dr.	lb.	.07¾- .07¾	.07½- .07¾	.07½- .07½
Muriate, 80% bgs	ton	36.40 -......	36.40 -......	36.40 -......
Nitrate, bbl.	lb.	.06 - .06½	.06 - .06½	.06 - .07¾
Permanganate, drums	lb.	.16 - .16½	.16 - .16½	.15 - .16
Prussiate, yellow, casks	lb.	.19 - .19½	.19 - .19½	.18 - .19
Sal ammoniac, white, casks.	lb.	.046- .05	.046- .05	.047- .05
Salsoda, bbl.	cwt.	.90 - .95	.90 - .95	.90 - .95
Salt cake, bulk	ton	16.00 -18.00	15.00 -17.00	17.00 -19.00
Soda ash, light, 58%, bags, contract	cwt.	1.32 -......	1.32 -......	1.32 -......
Dense, bags	cwt.	1.35 -......	1.35 -......	1.35 -......
Soda, caustic, 76%, solid, drums, contract	cwt.	2.80 - 3.00	2.80 - 3.00	3.00 - 3.10
Acetate, works, bbl.	lb.	.05 - .05¾	.05 - .05¾	.05½- .06
Bicarbonate, bbl.	cwt.	2.00 - 2.25	2.00 - 2.25	2.00 - 2.25
Bichromate, casks	lb.	.07 - .07½	.07 - .07½	.07 - .07½
Bisulphate, bulk	ton	12.00 -15.00	12.00 -15.00	3.00 - 3.50
Bisulphite, bbl	lb.	.03½- .03¾	.03½- .03¾	.03¾- .04
Chlorate, kegs	lb.	.07 - .07½	.06½- .07	.06½- .06½
Chloride, tech.	ton	12.00 -14.75	12.00- 14.75	12.00 -14.00
Cyanide, cases, dom.	lb.	.18 - .22	.18 - .22	.18 - .22
Fluoride, bbl.	lb.	.08¾- .09½	.08¾- .09½	.08¾- .09
Hyposulphite, bbl	lb.	2.50 - 3.00	2.50 - 3.00	2.50 - 3.00
Nitrate, bags	cwt.	2.15 -......	2.15 -......	2.35 -......
Nitrite, casks	lb.	.07½- .08	.07½- .08	.07½- .08
Phosphate, dibasic, bbl.	lb.	.03½- .03½	.03 - .03½	.03½- .03¾
Prussiate, yel. drums	lb.	.11½- .12	.11½- .12	.11½- .12
Silicate (30°, drums)	cwt.	.75 - 1.15	.75 - 1.15	.75 - 1.15
Sulphide, fused, 60-62%, dr.	lb.	.02¾- .03½	.02¾- .03	.03½- .04
Sulphite, crys., bbl	lb.	.02¾- .03	.02¾- .03	.02½- .03
Strontium nitrate, bbl.	lb.	.09 - .09½	.09 - .09½	.09 - .09½
Sulphur, crude at mine, bulk.	ton	18.00 -......	18.00 -......	18.00 -......
Chloride, dr	lb.	.04 - .05	.04 - .05	.04 - .05
Dioxide, cyl.	lb.	.09 - .10	.09 - .10	.09 - .10
Flour, bag	cwt.	1.55 - 3.00	1.55 - 3.00	1.55 - 3.00
Tin bichloride, bbl.	lb.	.15 -......	.15½-......	.15¾-......
Oxide, bbl.	lb.	.53 -......	.53 -......	.56 -......
Crystals, bbl.	lb.	.36 -......	.37 -......	.39 -......
Zinc chloride, gran., bbl.	lb.	.06½- .06¾	.06½- .06¾	.06½- .06¾
Carbonate, bbl.	lb.	.10½- .11	.10 - .10½	.10 - .11
Cyanide, dr.	lb.	.40 - .41	.40 - .41	.40 - .41
Dust, bbl.	lb.	.08½- .09	.08¾- .09	.09 - .10
Zinc oxide, lead free, bag.	lb.	.06½-......	.06½-......	.06½-......
5% lead sulphate, bags	lb.	.06½-......	.06½-......	.06½-......
Sulphate, bbl	cwt.	3.50 - 3.75	2.75 - 3.00	2.75 - 3.00

Oils and Fats

		Current Price	Last Month	Last Year
Castor oil, No. 3, bbl.	lb.	$0.13½-$0.14	$0.13½-$0.14	$0.13½-$0.14
Chinawood oil, bbl.	lb.	.14½-......	.14½-......	.15½-......
Coconut oil, Ceylon, tanks, N. Y.	lb.	.08 -......	.08 -......	.08½-......
Corn oil crude, tanks, (f.o.b. mill)	lb.	.08½-......	.09½-......	.09½-......
Cottonseed oil, crude (f.o.b. mill), tanks	lb.	.08¾-......	.09½-......	.08¾-......
Linseed oil, raw, car lots, bbl.	lb.	.098-......	.102-......	.096-......
Palm, Lagos, casks	lb.	.09 -......	.09½-......	.07¾-......
Niger, casks	lb.	.08½-......	.08¾-......	.07¾-......
Palm Kernel, bbl.	lb.	.08¾-......	.09¾-......	.09½-......
Peanut oil, crude, tanks(mill)	lb.	.10 -......	.10½-......	.09½-......
Rapeseed oil, refined, bbl.	gal.	.86 - .87	.86 - .87	.85 - .86
Soya bean tank (f.o.b. Coast)	lb.	.09½-......	.09½-......	.09¾-......
Sulphur (olive foots), bbl.	lb.	.10½-......	.11 -......	.09½-......
Cod, Newfoundland, bbl.	gal.	.65 - .67	.65 - .67	.66 - .67
Menhaden, light pressed, bbl.	gal.	.70 - .72	.70 - .72	.60 - .66
Crude, tanks(f.o.b. factory)	gal.	.48 -......	.48 -......	.40 -......
Whale, crude, tanks	gal.	.80 -......	.80 -......	......
Grease, yellow, loose	lb.	.07¾-......	.08½-......	.06¾-......
Oleo stearine	lb.	.10¾-......	.11 -......	.11¾-......
Red oil, distilled, d.p. bbl.	lb.	.09¾- .10	.09¾- .10	.09¾- .09½
Tallow, extra, loose	lb.	.08¾-......	.09¾-......	.08¾-......

Coal-Tar Products

		Current Price	Last Month	Last Year
Alpha-naphthol, crude, bbl.	lb.	$0.60 -$0.65	$0.60 -$0.65	$0.60 -$0.62
Refined, bbl	lb.	.80 - .85	.80 - .85	.85 - .90
Alpha-naphthylamine, bbl.	lb.	.32 - .34	.32 - .34	.35 - .36
Aniline oil, drums, extra	lb.	.14½- .15	.14½- .15	.15 - .16
Aniline salts, bbl	lb.	.24 - .25	.24 - .25	.24 - .25
Anthracene, 80%, drums	lb.	.60 - .65	.60 - .65	.60 - .65

Coal Tar Products (Continued)

	Current Price	Last Month	Last Year
Benzaldehyde, U.S.P., dr.... lb.	1.15 - 1.25	1.15 - 1.35	1.15 - 1.25
Benzidine base, bbl........ lb.	.67 - .70	.67 - .70	.70 - .72
Benzoic acid, U.S.P., kgs.... lb.	.57 - .60	.57 - .60	.58 - .60
Benzyl chloride, tech, dr.... lb.	.25 - .26	.25 - .26	.25 - .26
Benzol, 90%, tanks, works... gal.	.23 - .25	.23 - .25	.21 - .22
Beta-naphthol, tech., drums. lb.	.22 - .24	.22 - .24	.22 - .24
Cresol, U.S.P., dr.......... lb.	.14 - .17	.14 - .17	.18 - .20
Cresylic acid, 97%, dr., wks. gal.	.70 - .73	.73 - .75	.73 - .75
Diethylaniline, dr.......... lb.	.55 - .58	.55 - .58	.58 - .60
Dinitrophenol, bbl.......... lb.	.30 - .32	.30 - .31	.31 - .35
Dinitrotoluen, bbl.......... lb.	.17 - .18	.17 - .18	.17 - .18
Dip oil, 25% dr............ gal.	.26 - .28	.26 - .28	.28 - .30
Diphenylamine, bbl......... lb.	.42 - .43	.42 - .43	.45 - .47
H-acid, bbl................ lb.	.60 - .63	.60 - .63	.63 - .65
Naphthalene, flake, bbl..... lb.	.04½ - .05	.04½ - .05	.05 - .06
Nitrobenzene, dr........... lb.	.09 - .10	.09 - .10	.09 - .10
Para-nitraniline, bbl........ lb.	.55 - .56	.55 - .56	.52 - .53
Para-nitrotoluine, bbl....... lb.	.29 - .31	.29 - .31	.28 - .32
Phenol, U.S.P., drums....... lb.	.13 - .14	.13½ - .14	.17 - .18
Picric acid, bbl............ lb.	.30 - .40	.30 - .40	.30 - .40
Pyridine, dr................ lb.	1.75 - 1.90	1.75 - 1.90	1.90 -......
R-salt, bbl................. lb.	.44 - .45	.44 - .45	.47 - .50
Resorcinal, tech, kegs....... lb.	1.30 - 1.35	1.30 - 1.35	1.30 - 1.40
Salicylic acid, tech., bbl..... lb.	.30 - .32	.30 - .32	.30 - .32
Solvent naphtha, w.w., tanks. gal.	.30 - .35	.30 -......	.35 -......
Tolidine, bbl............... lb.	.86 - .90	.86 - .90	.95 - .96
Toluene, tanks, works....... gal.	.45 -.....	.45 -.....	.35 -....
Xylene, com., tanks........ gal.	.30 - .40	.30 - .35	.36 - .40

Miscellaneous

	Current Price	Last Month	Last Year
Barytes, grd., white, bbl..... ton	$23.00-$25.00	$23.00-$25.00	$23.00-$25.00
Casein, tech., bbl.......... lb.	.16 .16½	.16 - .16½	.16 - .18
China clay, dom., f.o.b. mine ton	10.00 -20.00	10.00 -20.00	10.00 -20.00
Dry colors:			
Carbon gas, black (wks.).. lb.	.08 - .13	.08 - .13	.06½ - .07
Prussian blue, bbl........ lb.	.35 - .36	.32 - .33	.31 - .32
Ultramine blue, bbl....... lb.	.06 - .32	.08 - .35	.08 - .35
Chrome green, bbl........ lb.	.30 - .32	.30 - .32	.27 - .30
Carmine red, tins......... lb.	6.00 - 6.50	6.00 - 6.50	5.50 - 5.75
Para toner............... lb.	.70 - .75	.70 - .75	.70 - .80
Vermilion, English, bbl.... lb.	1.85 - 2.00	1.90 - 2.00	1.80 - 1.85
Chrome yellow, C. P., bbl. lb.	.17 - .17½	.16 - .16½	.17 - .18
Feldspar, No. 1 (f.o.b. N. C.) ton	6.50 - 7.50	5.75 - 7.00	5.75 - 7.00
Graphite, Ceylon, lump, bbl. lb.	.07¾ - .08½	.08 - .08½	.08 - .09
Gum copal, Congo, bags..... lb.	.07¾ - .08	.07¾ - .08	.07¾ - .08
Manila, bags............. lb.	.16 - .17	.16 - .17	.15 - .18
Damar, Batavia, cases.... lb.	.24 - .25	.24 - .25	.25 - .25
Kauri, No. 1 cases........ lb.	.48 - .53	.48 - .53	.48 - .53
Kieselguhr (f.o.b. N. Y.).... ton	50.00 -55.00	50.00 -55.00	50.00 -55.00
Magnesite, calc............ ton	40.00 -......	40.00 -......	44.00 -......
Pumice stone, lump, bbl.... lb.	.05 - .07	.05 - .08	.05 - .07
Imported, casks.......... lb.	.03 - .40	.03 - .40	.03 - .35
Rosin, H................. bbl.	8.45 -......	9.25 -......	9.90 -......
Turpentine................ gal.	.53 -......	.58 -......	.58 -......
Shellac, orange, fine, bags... lb.	.61 -......	.61 -......	.51 - .52
Bleached, bonedry, bags... lb.	.56 - .58	.58 - .60	.54 - .56
T. N. bags................ lb.	.42 - .43	.44 - .45	.44 - .45
Soapstone (f.o.b. Vt.), bags.. ton	10.00 -12.00	10.00 -12.00	10.00 -12.00
Talc, 200 mesh (f.o.b. Vt.)... ton	9.50 -.....	9.50 -.....	10.50 -.....
300 mesh (f.o.b. Ga.)...... ton	7.50 -10.00	7.50 -10.00	7.50 -11.00
225 mesh (f.o.b. N. Y.).... ton	13.75 -.....	13.75 -.....	13.75 - 1

	Current Price	Last Month	Last Year
Wax, Bayberry, bbl.......... lb.	$0.28 -$0.32	$0.29 -$0.31	$0.24 -$0.26
Beeswax, ref., light........ lb.	.41 - .42	.41 - .42	.43 - .45
Candelilla, bags........... lb.	.22 - .23	.22 - .24	.24 - .27
Carnauba, No. 1, bags..... lb.	.36 - .38	.36 - .38	.54 - .55
Paraffine, crude			
105-110 m.p............ lb	.04¾ - .05	.04¾ - .05	.04¾ - .05

Ferro-Alloys

	Current Price	Last Month	Last Year
Ferrotitanium, 15-18%...... ton	$200.00-.....	$200.00-.....	$200.00-.....
Ferromanganese, 78-82%.... ton	105.00-.....	105.00-.....	100.00-.....
Spiegeleisen, 19-21%........ ton	33.00-.....	33.00-.....	31.00-32.00
Ferrosilicon, 14-17%........ ton	45.00-.....	45.00-.....	33.00-38.00
Ferrotungsten, 70-80%...... lb.	1.25	1.04- 1.10	.90- .95
Ferro-uranium, 35-50%...... lb.	4.50-.....	4.50-.....	4.50-.....
Ferrovanadium, 30-40%..... lb.	3.15- 3.75	3.15- 3.75	3.15- 3.75

Non-Ferrous Metals

	Current Price	Last Month	Last Year
Copper, electrolytic......... lb.	$0.19 -......	$0.20 -......	$0.14½-......
Aluminum, 96-99%.......... lb.	.24 - .26	.24 - .26	.24 - .25
Antimony, Chin. and Jap.... lb.	.09½......	.09½......	.10 -......
Nickel, 99%................ lb.	.35 -......	.35 -......	.35 -......
Monel metal, blocks........ lb.	.28 -......	.28 .28	.32 - .33
Tin, 5-ton lots, Straits...... lb.	.45½-......	.48¾	.51¾-......
Lead, New York, spot....... lb.	7.15 -......	7.25	6.10 -......
Zinc, New York, spot........ lb.	7.00 -......	6.67½- ..	6.05 - ..
Silver, commercial.......... oz.	.55¾-...	.56¾-	.57¾-
Cadmium.................. lb.	.85 - .95	.85 - .95	.60
Bismuth, ton lots........... lb.	1.70 -......	1.70 -......	1.85 - 2.10
Cobalt.................... lb.	2.10 - 2.50	2.10 - 2.50	2.50 -......
Magnesium, ingots, 99%..... lb.	.85 - 1.10	.85 - 1.10	.75 .80
Platinum, ref............... oz.	70.00- 72.50	70.00 72.50	85.00 ..
Palladium, ref.............. oz.	38.00- 40.00	38.00 40.00	50.00 52.00
Mercury, flask.......... 75 lb.	124.00-......	123.50-......	124.50-......
Tungsten powder.......... lb.	1.20- 1.35	1.10- 1.15	1.05-......

Ores and Semi-finished Products

	Current Price	Last Month	Last Year
Bauxite, crushed, wks....... ton	$7.50- $8.00	$7.50- $8.50	$5.50- $8.75
Chrome ore, c.f. post........ ton	22.00- 25.00	22.00- 24.00	22.00- 23.00
Coke, fdry., f.o.b. ovens..... ton	2.85- 3.00	2.85- 3.00	2.85- 3.00
Fluorspar, gravel, f.o.b. Ill.... ton	18.00- 20.00	18.00- 20.00	14.50-......
Ilmenite, 52% TiO_2, Va..... lb.	.00¾ .00¾	.00¾- .00¾	.00¾-......
Manganese ore, 50% Mn., c.i.f. Atlantic Ports....... unit	.34 - .37	.34 - .37	.36 - .38
Molybdenite, 85% MoS_2 per lb. MoS_2, N. Y.......... lb.	.48 - .50	.48 - .50	.48- .50
Monazite, 6% of ThO_2...... ton	130.00-......	130.00-......	120.00-......
Pyrites, Span. fines, c.i.f..... unit	.13 -......	.13 -......	.13½-......
Rutile, 94-96% TiO_2........ lb.	.11 - .13	.11 - .13	.11 - .13
Tungsten, scheelite, 60% WO_3 and over....... unit	15.00	11.25 -11.50	11.25 -11.50
Vanadium ore, per lb. V_2O_5.. lb.	.28	.28 -......	.25 - .28
Zircon, 99%............. lb.	.03 -.....	.03 -	.03 -......

CURRENT INDUSTRIAL DEVELOPMENTS

New Construction and Machinery Requirements

Abrasive Products Plant — Bay State Abrasive Products Co., O. S. Buckman, Westboro, Mass., plans the construction of a plant. Estimated cost $50,000. Architect not selected.

Acetylene Plant—Linde Air Products Co., subsidiary of Union Carbon & Carbide Co., 30 East 42nd St., New York, N. Y., plans the construction of an acetylene plant at Davenport, Ia. Estimated cost $125,000.

Acetylene Plant — Prest-O-Lite Co., 550 East 17th St., Wichita, Kan., awarded contract for a 1 story, 58 x 125 ft. acetylene plant, to Robertson Construction Co., 201 Bitting Bldg. Estimated cost $40,000.

Air Reduction Products Plant—Air Reduction Co., Lafayette and Michigan Sts., Toledo, O., will build a factory. Estimated cost $250,000. Work will be done by owners' forces.

Annealing Building — Heppenstall Forge & Knife Co., 4620 Hatfield St., Pittsburgh, Pa., awarded contract for a 1 story, 60 x 71 ft. annealing building at 47th and Harrison Sts., to Rust Engineering Co., American State Bank Bldg., Pittsburgh. Estimated cost $40,000.

Annealing Building—King Terminal Co., 50 State St., Boston, Mass., plans to rebuild 2 story building, recently destroyed by fire at 74 K St., South Boston. Estimated cost $40,000. E. E. Erickson, 50 State St., Boston, is engineer. New England Annealing & Tool Co., 74 K St., South Boston, is lessee.

Battery Plant — Prest-O-Lite Storage Battery Co., 80 South Davenport St., Toronto, Ont., awarded contract for the construction of a storage plant, to Wells & Gray Ltd., Toronto. Estimated cost $125,000.

Battery Factory—Willard Storage Battery Co., East 131st St. and St. Clair Ave., Cleveland, O., plans the construction of a storage battery factory at South Gate, Calif. Estimated cost $250,000.

Brass Foundry — Bridgeport Brass Co., R. Day, Gen. Mgr., Bridgeport, Conn., awarded contract for a 1 story, 75 x 200 ft. plant on Housatonic Ave., to Hewlett Co., 886 Main St., Bridgeport. Estimated cost $100,000.

Brass Foundry — Eberhardt & Weidner, 2011 Fullerton Ave., Chicago, Ill., will soon award contract for a 1 story, 50 x 50 ft. addition to brass foundry.

Bronze Foundry—Michel & Pfeffer Iron Works, 10 and Harrison Sts., San Francisco, Calif., plans first unit of plant to include bronze foundry, etc., at South San Francisco. Estimated cost $200,000.

Carbon Factory — National Carbon Co., W. J. Darling, Purch. Agt., West 117th St. and Madison Ave., Cleveland, O., awarded contract for alterations to carbon factory to Masters & Mullen Construction Co., 4900 Euclid Ave., Cleveland. Estimated cost $40,000.

Cement Plant — Hercules Portland Cement Co., Washington and 4th Sts., Los Angeles, Calif., will soon receive bids for an 8 story cement plant, to include grinding mill, crushing plant, packing plant, silos, kilns, etc., at Torrance. Estimated cost $2,500,000. Private plans.

Cement Plant — Vancouver Cement Co. Ltd., Vancouver, B. C., plans the construction of a cement plant, 380,000 bbl. capacity at Popleum, B. C.

Chemical Plant—Grasselli Chemical Co., B.-M. Bldg., Birmingham, Ala., plans to rebuild plant recently destroyed by fire. Loss $250,000.

Chemical Building—New York, Chicago & St. Louis R.R., C. Herr, West 3rd St. and St. Clair Ave., Cleveland, O., will soon award contract for a 1 story, 32 x 52 ft. chemical building, at Huron, O. Estimated cost $40,000. A. C. Harvey, Cleveland, is chief engineer.

Chemical Factory Addition — Furst-McNess Co., F. E. Furst, Pres. and Treas., 120 East Clark St., Freeport, Ill., awarded contract for a 5 story addition to chemical factory to Madsen Construction Co., 527 Second Ave., Minneapolis, Minn. Estimated cost $150,000.

Chemical Plant — Naugatuck Chemical Co., Elm St., Naugatuck, Conn., awarded contract for a 1 story, 50 x 100 ft. chemical manufacturing plant on Elm St. to Tracy Bros. Co., 52 Benedict St., Waterbury. Estimated cost $20,000.

Chemistry Building — Bd. of Trustees, Indiana University, J. Craven, Bloomington, Ind., is having plans prepared for the construction of a chemistry building. Estimated cost $400,000. R. F. Daggett, 922 Continental Bank Bldg., Indianapolis, is architect.

Chlorine Products Factory — Westvaco Chlorine Products Inc., South Charleston, W. Va., awarded contract for addition to factory. Estimated cost $1,225,000.

Copper Refinery — International Nickel Co., 67 Wall St., New York, N. Y., and Consolidated Mining & Smelting Co., Canadian Pacific Bldg., Toronto, Ont., will build a copper refinery 120,000 ton annual capacity at Copper Bluff, Ont. Estimated cost $4,000,000. Work will be done by day labor.

Cracking Plant—Union Oil Co., Union Oil Bldg., Los Angeles, Calif., awarded contract for the construction of a cracking plant, to M. W. Kellogg Co., Danforth Ave., Jersey City, N. J. Estimated cost $700,000.

Dental Plant Addition—Cleveland Dental Mfg. Co., W. L. Truesdell, Pres., 3307 Scranton Rd., Cleveland, O., awarded contract for a 3 story addition to factory at 3307 Scranton Rd., to W. J. Schirmer Co., 1720 Euclid Ave., Cleveland. Estimated cost $60,000.

Foundry and Enameling Plant, etc. — Rundle Mfg. Co., 27th St. and Cleveland Ave., Milwaukee, Wis., awarded contract for a 150 x 330 ft. foundry, 100 x 140 ft. cleaning building, 100 x 180 ft. enameling plant, etc., at Camden, N. J., to Barclay White & Co., 22 North 36th St., Philadelphia, Pa. Estimated cost $1,000,000.

Glass Factory—Pittsburgh Plate Glass Co., Frick Bldg., Pittsburgh, Pa., has acquired a site and plans the construction of a plant at Henryetta, Okla. Estimated cost $1,000,000. Private plans.

Hydrogen Gas Plant—Tokyo Electric Co., Kawasaki, Japan, awarded contract for the construction of a hydrogen gas plant at Kawasaki, to H. K. Ferguson Co., Hanna Bldg., Cleveland, O.

Laboratory—Bell & Howell Co., W. H. Haun, Mgr., 1801 Larchmont Ave., Chicago, Ill., manufacturers of cameras, is having plans prepared for the construction of a laboratory building at North Rockwell St. and Belle Plaine Ave. Estimated cost $90,000. Pond & Pond, Martin & Lloyd, 180 North Michigan Ave., Chicago, are architects.

Laboratories—Dept. of Public Works, Parliament Bldg., Ottawa, Ont., plans additions to forest products and hygiene laboratories, also laboratory for Dept. of Mines. Estimated total cost $120,000.

Laboratory—Dept. of Ways & Means, Albany, N. Y., appropriated $475,000 for the construction of a laboratory for the New York State college of home economics at Cornell University.

Laboratory (Chemical) — Henry Bower Chemical Co., 29th St. and Grays Ferry Rd., Philadelphia, Pa., plans a 2 story laboratory. Ballinger Co., 12th and Chestnut Sts., Philadelphia, is architect.

Laboratory (Medical Research)—Rockefeller Institute for Medical Research, F. T. Gates, Pres., 66th St. and York Ave., New York, N. Y., plans a 7 story, 60 x 196 ft. laboratory. Estimated cost $1,000,000. Coolidge, Shipley, Bulfinch & Abbott, Ames Bldg., Boston, Mass., are architects.

Laboratories, etc. — Academy of Our Lady, c/o G. F. Berger, Madison and Bryan Sts., Peoria, Ill., will soon receive bids for a 4 story school including laboratories, etc. Estimated cost $200,000. H. B. Dox, Lehman Bldg., Peoria, is architect.

Laboratories, etc.—Bd. of Education, D. Hamilton, Chn., 178 Worthington St. E., North Bay, Ont., is having preliminary plans prepared for the construction of a vocational school including laboratories, etc. Estimated cost $260,000.

Lacquer Shop — E. Ingraham Co., 392 North Main St., Bristol, Conn., had plans prepared for a 5 story, 50 x 80 ft. lacquer shop on North Main St. Estimated cost $75,000. M. J. Unkelbach, 52 Main St., New Britain, Conn., is architect.

Lacquer Factory — Jones-Dabney Co., 1481 South 11th St., Louisville, Ky., awarded contract for a 3 story, 50 x 80 ft. lacquer factory to A. Markham & Co., 432 South Floyd St., Louisville. Estimated cost $75,000.

Leather Factory—Agoos Leather Co., 138 Boston St., Lynn, Mass., awarded contract for addition and alterations to leather factory, to Dineen Construction Co., 23 Central Ave. Estimated cost $40,000.

Leather Goods Factory—Hugh Carson & Co. Ltd., Albert St., Ottawa, Ont., plans addition to leather goods factory. Estimated cost $60,000. Architect not selected.

Lime Plant—Inland Lime & Stone Co., subsidiary of Inland Steel Co., 38 South Dearborn St., Chicago, Ill., plans development of a large quarry near Manistique, Mich., for production of chemical and metallurgical lime.

Match Factory—Columbia Match Co., St. Johns, Que., plans the construction of a factory. Estimated cost $250,000. Architect not selected.

Nickel Plating Plant—Herald Publishing Co. Ltd., 15 Jurors St., Montreal, Que., is in the market for a nickel plating plant with large vats for heavy work.

Plant—Surface Combustion Co., 2375 Dorr St., Toledo, O., awarded contract for a 1 story, 170 x 180 ft. plant to A. Bentley & Sons, Belmont St., Toledo. Estimated cost $200,000.

Paint and Varnish Factory—Armstrong Paint & Varnish Works, R. J. Kennedy, V. Pres., 1230 South Kilbourne Ave., Chicago, Ill., awarded contract for addition to factory to Austin Co., 16112 Euclid Ave., Cleveland. Estimated cost $40,000.

Paint Factory—General Color Products Co., 2110 Natchez Ave., Chicago, Ill., awarded contract for a 1 story, 100 x 131 ft. factory. Estimated cost $45,000.

Paper Plant — Detroit Wax Paper Co., 547 Harper Ave., Detroit, Mich., is having plans prepared for a 1 story, 210 x 600 ft. plant for the manufacture of cardboard and wax paper, on Pleasant Ave., River Rouge. Estimated cost $600,000. Private plans.

Paper Factory — Smith Paper Co., N. Bussey, Pres., Lee, Mass., awarded contract for two additional units to paper factory, 2 and 3 story, 70 x 170 and 60 x 10) ft., to Lunch Bros. Co., 225 High St., Holyoke, Mass.

Petroleum Building—University of Tulsa, 121 East 4th St., Tulsa, Okla., plans a 2 story petroleum building on campus. Estimated cost $150,000. Architect not announced.

Petroleum Plant—Pan American Petroleum Co., Jacksonville, Fla., awarded contract for a 2 story, 50 x 100 ft. petroleum plant, on Main and Second Sts., to W. T. Hadlow, 3 North Forsyth St., Jacksonville. Estimated cost $50,000.

Powder Factory — Construction Quartermaster, U. S. Army, at Arsenal Picatinny, N. J., is receiving bids for a 2 story powder factory at Picatinny Arsenal, Dover, N. J. Estimated cost $125,000.

Polish Plating Material Plant — J. C. Miller Co., Weiss Service Bldg., Grand Rapids, Mich., plans the construction of a 2 story polish plating material plant on Seward St. 300,000 gal. tankage for mineral acids. Estimated cost $50,000. Architect not selected.

Pottery Plant — Franklin Pottery Co., Lansdale, Pa., awarded contract for a 2 story, 80 x 500 and 68 x 120 ft. factory, to Powell Construction Co., Ardmore, Pa.

Pottery Plant — Homer Laughlin China Co., Newell, W. Va., awarded contract for a 1 story, 400 x 1,200 ft. pottery plant, to H. K. Ferguson Co., Hanna Bldg., Cleveland, O. Estimated cost $500,000, also three new tunnel kilns to Harrop Ceramic Service Co., 310 West Broad St., Columbus. $500,000.

Pottery Plant — Trenton Potteries Co., Clinton and Ott Sts., Trenton, N. J., will soon award contract for the construction of a 5 story, 60 x 275 ft. pottery. Lockwood, Greene & Co., 1 Pershing Sq., New York, N. Y., Engrs.

Pulp and Paper Mill—City of Everett, Wash., plans the construction of a pulp and paper mill, 150 ton daily capacity. Estimated cost $4,500,000.

Pulp and Paper Mill—Crown Willamette Paper Co., 248 Battery St., San Francisco, Calif., has retained V. D. Simons, 431 North Michigan Ave., Chicago, Ill., Ind. Engr., to design, supervise and reconstruct pulp and paper mill to include new paper machine, sulphite bleachery, and new wood mill at Camas, Wash. Estimated cost $3,000,000.

Pulp and Paper Mill—Puget Sound Pulp & Timber Co., Everett, Wash., plans the construction of a pulp and paper mill. Estimated cost $3,000,000.

Radio Factory—Steinite Radio Co., Fort Wayne, Ind., awarded contract for a 4 story, 202 x 500 ft. factory including 200 x 500 ft. machine shop, 45 x 50 ft., boiler house, etc. to Buesching & Hagerman, 402 East Superior St., Fort Wayne. Estimated cost $400,000.

Rayon Factory — American Glanzstoff Co., Elizabethtown, Tenn., will receive bids late in April for the construction of second unit of rayon factory. Estimated cost $6,000,000.

Refinery (Oil) — Carnegie Refining Co., Heidelberg, Pa., is having plans prepared for a 3 story, 44 x 160 ft. oil refinery in Allegheny county. Estimated cost $100,000. H. S. Bell, Woolworth Bldg., New York, N. Y., is engineer.

Refinery (Oil)—Grayburg Oil Co., S. M. Newton, Pres., San Antonio, Tex., have acquired a 280 acre site and plans the construction of an oil refinery. Estimated cost $2,000,000. Private plans.

Rubber Factory—Boston Woven Hose & Rubber Co., 29 Hampshire St., Cambridge, Mass., awarded contract for a 3 story addition and alterations to factory, to W. Fillmore Co., 25 Cherry St., Cambridge.

Rubber Factory—Canadian Goodrich Co. Ltd., King St., Kitchener, Ont., awarded contract for a 4 story, 60 x 90 ft. addition to rubber factory to Dunker Bros., 58 Louisa St., Kitchener. Estimated cost $100,000.

Rubber Factory—B. F. Goodrich Rubber Co., South Main St., Akron, O., awarded contract for a 2 and 3 story, 134 x 405, 134 x 243, 102 x 103 and 62 x 102 ft. factory at Thomaston, Ga., to Batson-Cook, West Point, Ga. Estimated cost $1,500,000, also plans a plant at Atlanta. $1,500,000.

Rubber Factory — Metcalfe Heels Ltd., C. M. Iredale, Mgr., Montrose St., Preston, Ont., prices and catalogs on complete equipment for the manufacture of rubber heels. Estimated cost $25,000.

Rubber Reclaiming Plant — Goodyear Tire & Rubber Co., 1144 East Market St., Akron, O., awarded contract for the construction of a rubber reclaiming plant at Gadsden, Ala., to Adams & Co., Atlanta, Ga. Estimated cost $1,000,000.

Silos or Storage Bins — Canada Cement Co., Northern Ontario Bldg., Toronto, Ont., plans the construction of silos or storage bins for storing cement in bulk, 100,000 bbl. initial capacity. Bagging machinery will be required.

Smelting Plant—H. Kramer & Co., 2125 Loomis St., Chicago, Ill., will soon award contract for the construction of a smelting plant. Estimated cost to exceed $100,000. D. S. Klafter, 100 North La Salle St., Chicago, is architect.

Smelting Plant Addition — Michigan Smelting & Refining Co., 7885 Joseph Campau Ave., Detroit, Mich., awarded contract for a 1 story, 150 x 300 ft. and addition to smelting plant. Estimated cost $125,000.

Soap Factory—F. W. Fitch Co., 304 15th St., Des Moines, Ia., awarded contract for the construction of a soap factory to Zitterell-Mills Co., Webster City, Ia. Estimated cost $50,000.

Soap Factory — Lever Bros. Co., 164 Broadway, Cambridge, Mass., will build a 5 story, 38 x 40 ft. soap factory. Stone & Webster Engineering Corp., 49 Federal St., Boston, is engineer. Work will be done by separate contracts; also taking bids for four 1,000,000 lb. steel tanks. C. T. Main Inc., 201 Devonshire St., Boston, Engr., Owners awarded contract for a 1 story Rinso soap powder building to Walsh Bros., 150 Hampshire St., Cambridge.

Soap Factory — Procter & Gamble Co., Port Ivory, N. Y., awarded contract for a 1 and 3 story addition to soap factory at Staten Island, N. Y., addition to factory at St. Louis, Mo., to H. K. Ferguson Co., Hanna Bldg., Cleveland, O. Each estimated to cost $250,000; also takes bids after Apr. 20 for a factory at Baltimore, Md. $4,000,000. H. Manley, 5 East 53rd St., New York, N. Y., is architect.

Spinning Plant — Magee Copper Co., Bloomsburg, Pa., awarded contract for a 4 story, 75 x 280 ft. spinning plant, to Dresser Co., The Arcade, Cleveland, O. Estimated cost $300,000.

Storage Tanks, Cracking Units, etc. — Humble Oil & Refining Co., Humble Bldg., Houston, Tex., has acquired a 720 acre site and plans the construction of thirty additional steel storage tanks, seven cracking units, etc., at Ingleside, Tex. Private plans.

Tile Factory—Galassi Mosaic & Tile Co., 11 Bennett St., Boston, Mass., awarded contract for a 1 story tile factory at Brighton, Mass. Estimated cost $40,000.

Varnish Factory — Standard Varnish Works, 116 East Jefferson St., Los Angeles, Calif., plans the construction of a varnish factory. Estimated cost $100,000.

Wood Preserving Plant—Alberta Wood Preserving Co., Calgary, Alta, plans the construction of a creosoting plant at Port Moody, B. C. Estimated cost $500,000.

Wood Preserving Plant—W. J. Smith Wood Preserving Co., Denison, Tex., is having preliminary plans prepared for the construction of a plant to include complete equipment. Estimated cost $75,000. Private plans.

Wrapping Paper Plant—DuPont Cellophane Co., Abbott Rd., and Orchard Park, Buffalo, N. Y., subsidiary of E. I. DuPont de Nemours, 4th Ave. and 32nd St., New York, N. Y., will build first unit of cellophane wrapping paper plant at Old Hickory, Tenn. Estimated cost $2,000,000 to $3,000,000. Private plans. Work will be done by day labor.